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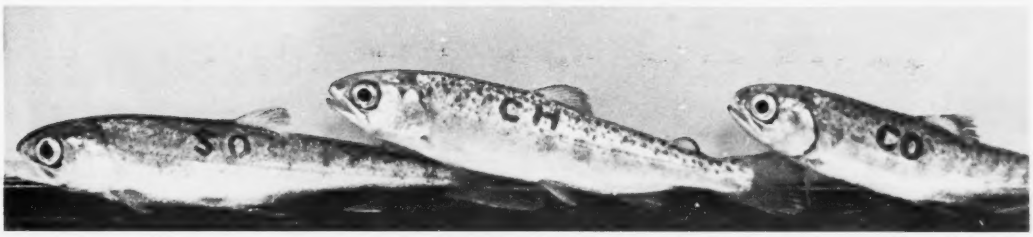

Marking Fishes and Invertebrates

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MFR PAPER 1067

Tetracycline, coded wire, and cold branding are three promising fish marking methods.

Marking Fishes and Invertebrates. I. State of the Art of Fish Branding

HOWARD L. RAYMOND

ABSTRACT

Advantages and disadvantages of various methods of marking fish are briefly described. Evolution of branding as a method of marking fish (mainly juvenile Pacific salmon, Oncorhynchus *spp., and steelhead trout,* Salmo gairdneri*) is traced from use of a wood burning tool to present day cold and laser-beam branding. Problems associated with cold branding today are stressed, particularly the variability in retention of brands. Suggested causes of variability include: (1) differences between fish markers with respect to duration of, and pressure of, application of the branding tool on the fish; (2) physiological differences among races, species, and sizes of fish; and (3) differences between smolting and nonsmolting fish, feeding and nonfeeding fish, tool sizes, and symbols. Additional research along the lines suggested above could help isolate the major causes of variability and bring us closer to standardizing the methodology required to affix permanent brands on fish.*

INTRODUCTION

Fishery scientists have long recognized the need to identify groups of fish and individual fish by marking. Methods of marking used to date include fin-clipping, external tagging, tattooing, tetracycline injection, coded-wire tagging, and branding. While some methods have been partially successful, none has been entirely satisfactory.

Most experiments with Pacific salmon, *Oncorhynchus* spp., and steelhead trout, *Salmo gairdneri*, have been with fin clips. In recent years, mass fin-clipping of juvenile salmon, released from hatcheries on the Pacific Coast of North America, has provided sufficient data to permit evaluation of the hatchery contribution of fall chinook, *O. tshawytscha*, to the sport and commercial fishery (Worlund, Wahle, and Zimmer, 1969). Advantages of fin-clipping are:

(1) Permanence of the mark if the fin is properly excised.

(2) Easy identification by fishermen.

(3) Inexpensive to mark.

Disadvantages are:

(1) High mark mortality on some combainations of excised fins, especially pectoral and maxillary. Weber and Wahle (1969) reported that sockeye salmon, *O. nerka*, with excised adipose-left maxillary fins suffered a 39 percent higher mortality than those marked with tetracycline.

(2) Fin regeneration—if the fin is not properly excised, there is considerable regeneration, particularly on the anal fin. Worlund et al. (1969) indicated 5-11 percent regeneration on ventral and maxillary clips. We noted up to 35 percent regeneration of partially excised anal fins in 1971.

(3) Limited number of combinations. Only four fins of salmon and trout are considered adequate for experiments by researchers—the adipose, dorsal, and the left and right ventrals. Excision of these fins would allow only two experiments between comparably paired groups, or up to a maximum of 10 combinations of single and double fin-clips, which would be totally inadequate for a river system such as the Columbia, with its extensive network of hatcheries. In past years researchers have been forced to use more inferior clips such as pectoral, anal, and maxillary at some hatcheries, creating a potential bias on the interpretation of results.

External tags, such as spaghetti and dart tags, are useful in experiments involving small numbers of fish and for limited periods. Such

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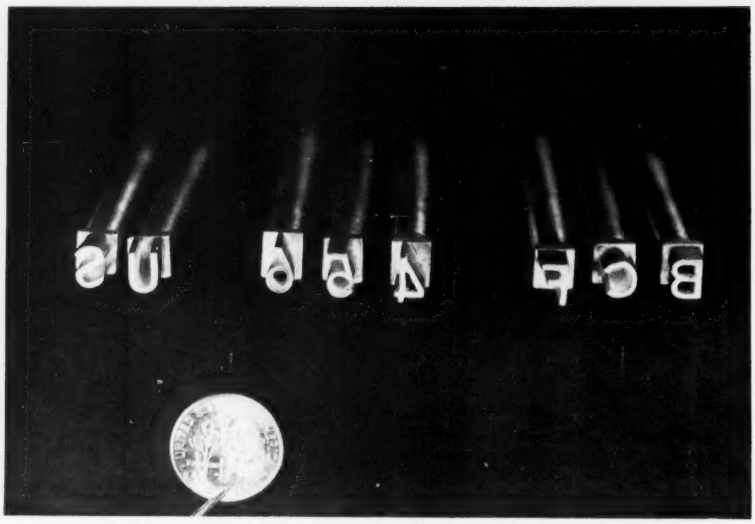


Figure 1.—Closeup of solid silver tips on marking tools; 10-cent piece shows size relationship. (Courtesy Groves and Novotny, 1965.)

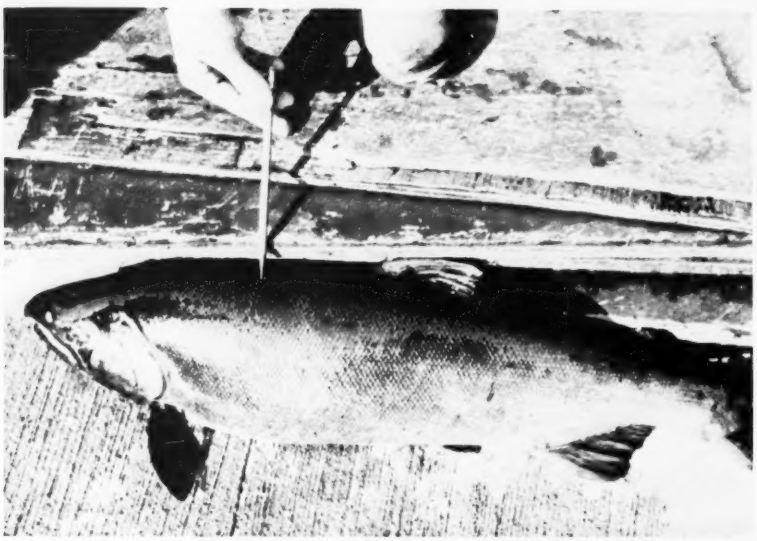


Figure 2.—Brand mark "FC" on 2-year-old adult coho salmon. Mark appears dark because of absence of reflective pigment and altered scale growth. (Courtesy Groves and Jones, 1969.)

methods are not practical on a production scale, since the tags generally require more time to apply than other marks and are often rejected or lost as the fish grow.

Tattooing also is useful in short-term experiments (Schoeneman, Pressey, and Junge, 1961) but is also limited in duration and numbers of combinations.

Tetracycline is most promising not only as a permanent mark but as an excellent control for assessing fin-clip or other mark mortalities in hatcheries (Weber and Wahle, 1969). Its disadvantages are limited combinations and lack of external marking. The fish must be killed and a vertebra removed to determine whether the fish is marked.

The coded wire identification system developed by Jefferts, Bergman, and Fiscus (1963) appears promising. Its major advantage is the almost unlimited number (10^6) of experimental groups that can be identified. Disadvantages are high initial cost of equipment and tags as well as some tag loss and malfunctioning of tagging gear and adult detection equipment. Recent experiments using coded wire tags for marking juvenile fish are discussed by Ebel (1974).

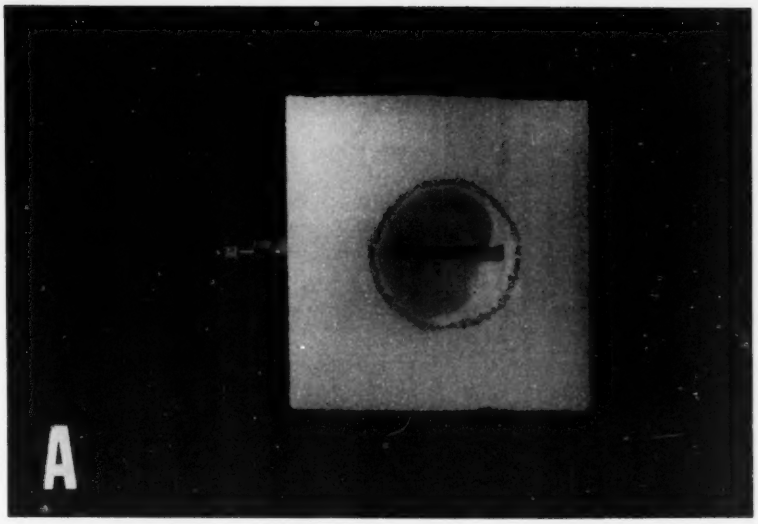
Marking with a laser beam has recently been attempted and may afford another means of identifying origin of fish. Maximum disadvantage to date is cost ($26/1,000 fish) and inability to produce accurate beams of the wavelengths of light required. Recent field trials with a laser device have been disappointing. Laser-marked coho salmon, released in the Columbia River and subsequently recovered during their downstream migration, actually looked as though holes had been blown through their bodies. The problem apparently was fluctuating voltage of the machine. It appears that considerable research is still required in this field before laser branding becomes feasible.

Branding of fish was reported by Buss (1961), who used a wood-burning pencil to mark juvenile brook trout, *Salvelinus fontinalis*. He reported that some brands remained visible after 21 months and one after 4 years. Johnson and Fields (1959) tried to mark fingerling steelhead trout by applying to the skin surface a nichrome wire electrically heated to white heat. This induced injuries which were slow to heal, and after 5 months no distinguishable marks or scars were left. Similarly, white hot wire was used by Watson (1961) to mark young

Atlantic herring, *Clupea harengus harengus*. He reported that scars were discernible after 7 months, but differences between marks were evident only during the first few days.

Groves and Novotny (1965) marked fish with a specially designed marking tool immersed in boiling water (Fig. 1). All fish had visible marks after 10 months. Marks grew with the fish which increased in size from 100 to 200 mm. In 1965, 15,000 yearling coho salmon were branded at the Fish Commission of Oregon OxBow Hatchery, fin-clipped, and released into the Columbia River (Groves and Jones, 1969). The clipped fins permitted a double check of all branded fish. Six months later 171 of the fish returned as 2-year-old adults (Fig. 2). All had clips and brands intact. Subsequently, 30 additional fish, all with identifiable brands and clips, were observed among returning 3-year-olds of the same group.

Cold branding was initiated by Fujihara and Nakatani (1967) and by Everest and Edmundson (1967). They used a slurry of dry ice and ethanol (−78°C). Mighell (1969) tried this method and found it unsuccessful when large numbers of fish were marked rapidly. Ice and frozen mucus accumulated on the branding tool and apparently disrupted heat transfer between the fish and the tool; resultant marks were poor. Good marks were produced when the tool was cleaned regularly, but the rate of marking was greatly reduced. When liquid nitrogen (−196°C) was used, however, the tool remained free of ice and mucus and produced consistently clear brands at rapid rates. The marking tool, the reservoir to hold the liquid nitrogen, and a closeup of the male connector used for rotating or changing marking tools are shown in Figure 3. Mighell marked juvenile chinook, coho, and sockeye salmon, and steelhead trout ranging from 50 to 160 mm in fork length, varying brand application times from ½ to 3 sec. In general, the marks remained dark with sharp definition for about 7 weeks, after which they became lighter in hue and consisted mainly of altered scales and scarred epidermis (Fig. 4).



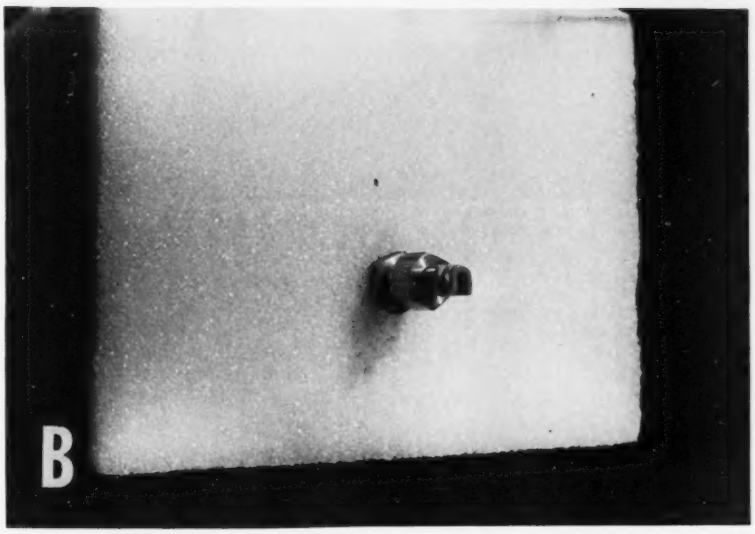


Figure 3.—(A) View from the top of cold-branding apparatus; lid is removed to show reservoir for liquid nitrogen (outlined in black on foam). (B) Closeup of male tubing connector and "U"-shaped cold-branding tool mounted for marking. (Courtesy Mighell, 1969.)

Mighell concluded that more work is needed to determine the optimum duration of brand application to the epidermis of the fish and the best size and age at which brands should be applied to ensure identifiable development and maximum retention. From his work he felt that fish should be over 55 mm in length (marks on fish smaller than 55 mm disappeared

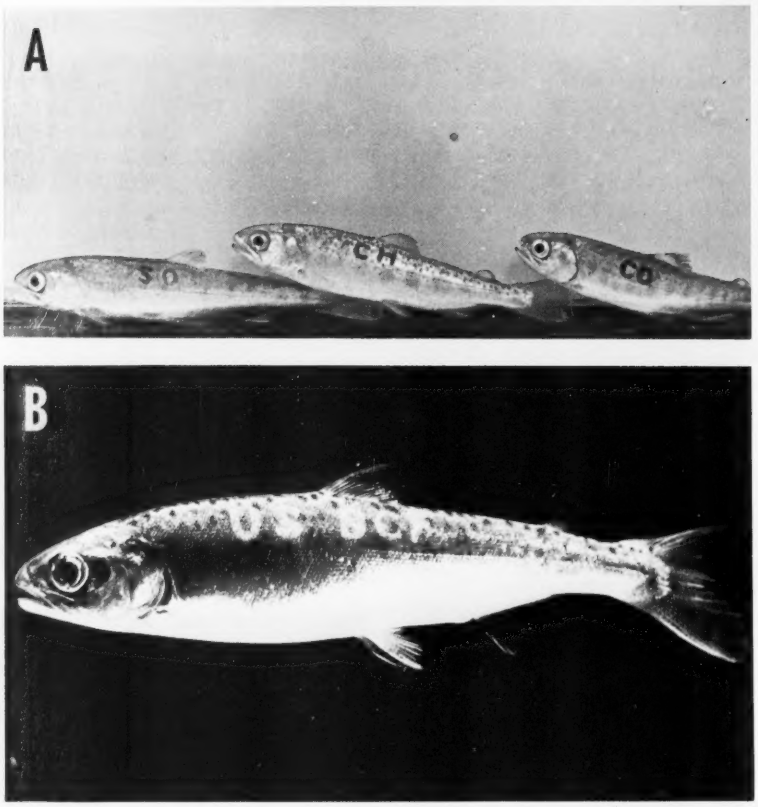


Figure 4.—(A) Cold brands 48 hours after marking. (B) Cold brand 3 months after marking. (Courtesy Mighell, 1969.)

after 3 weeks) and brands should be applied for at least 1 second.

Smith (1973) tried to determine why marks fade on fish under 55 mm by marking various groups of chinook, coho, and sockeye salmon, ranging from 32 to 48 mm. His findings substantiated those of Mighell. Most marks could not be distinguished after 2 months. They feel the problem is primarily lack of maturity of the scale producing cells.

Work on the Columbia River by the National Marine Fisheries Service (NMFS) has resulted in the branding of several million juvenile salmon and trout annually since 1964. Our primary requirement in the initial phases of these studies was a short-term mark with a capacity for numerous combinations (which the brand provided). We were not looking for adult returns. In more recent years, though, branded adults started returning to hatcheries such as OxBow on the lower Columbia River, Rapid River on the Salmon River (a tributary of the Snake River), to the Seattle laboratory of NMFS from releases by Mighell, and to the University of Washington in Seattle. Furthermore, the fish counters at dams started seeing a number of brands and sportsmen reported catching branded fish.

In recent years branding of fish has spread from the Pacific Northwest to other parts of the United States and even to Kenya in Africa. The most extensive branding program outside of the Pacific Northwest was probably that held in the Great Lakes Region (R. Saalfeld, Great Lakes Fisheries Commission, pers. comm., 1971). A total of 246,000 yearling lake trout, *Salvelinus namaycush*, were fin-clipped, branded, and released in southern Lake Michigan in the spring of 1969. Of those recovered, 80 percent had marks, but visibility was extremely varied, ranging from barely perceptible to very perceptible. Saalfeld concluded that if identification depended on the brand alone (no fin-clip), a high percentage of marked fish would have gone undetected.

The Washington Department of Game marked juvenile steelhead trout in 1969 using a larger mark than that previously applied in our Columbia River studies. Adults returning from these releases bore highly visible brands as reported by the fish counters who observed migrants as they passed by the viewing window in the fish ladder of Little Goose Dam on the Snake River (Tony Eldred, Washington Department of Game, Moses Lake, Washington, pers. comm.). The obvious legibility of this brand indicated that brand size might be a significant factor in permanency of the brand on fish.

By 1972, the consensus of most researchers was that branding had great potential but results were highly variable. Why did some fish retain clear brands to adulthood and not others? Is the variation related to difference in size or condition of fish, or does the time of year make a difference? Is there a method yet unknown that is less variable?

With these thoughts in mind, we held a workshop in Seattle 17-19 January 1972, assembling many qualified workers in the field of branding. Discussion panels included: (1) evolution of branding; (2) methodology; (3) physiology; (4) results to date; (5) where we are in the state of the

art of branding; and (6) additional research required to perfect branding of fish.

Conferees generally concluded that permanent brands on fish could be obtained if the problems with fluctuation in clarity and retention of brands could be resolved. Some of the reasons for the high variability and obvious areas where research is still required to perfect brand methodology include:

(1) Improperly sized brands for the size of fish being marked.

(2) Use of both open and closed brands and simple and complex symbols on comparable groups of fish.

(3) Branding comparable lots of fish on different parts of the body (there is considerable variation in both retention and clarity of brand, depending upon area of branding on fish).

(4) Differences between performance of fish markers branding fish, with respect to time and pressure of application, may be the single most important cause of variation in brand retention to adulthood. If too much pressure is used or the brand is held on the fish too long, excess cellular damage frequently results. Actual scarring occurs—the mark folds up and disappears. By contrast, if application time is too short, the marks will not be retained for more than a few months.

(5) Degree of scale development and smoltification and condition of fish at time of marking.

(6) Physiological differences among race, species, and size of fish.

Following the workshop, some additional research commenced on brand size, shape, and topical location. Donn Park (NMFS, Northwest Fisheries Center, Seattle, pers. comm.) compared different brand sizes and shapes placed above the lateral line near the dorsal fin on salmon and steelhead smolts at Little Goose Dam on the Snake River. Adult returns of fish marked with standard size letters in 1968-70 (Ebel, Park, and Johnsen, 1973) served as comparative data for the 1971-72 tests. Results (Table 1) indicated that retention is considerably improved by using larger brands. Furthermore, Park found that symbols with the simplest lines and fewest angles produced the sharpest brands.

Raleigh, McLaren, and Graff (1973) in Pennsylvania, using liquid nitrogen as a coolant, have obtained identifiable and reasonably durable brands on three species of trout: rainbow (*Salmo gairdneri*), brown (*Salmo trutta*), and brook (*Salvelinus fontinalis*), and three species of centrarchids: smallmouth bass (*Micropterus dolomieui*), rock bass (*Ambloplites rupestris*), and redbreast sunfish (*Lepomis auritus*).

Table 1.—Legibility of brands on returning adult steelhead trout and chinook salmon as related to brand size at time of marking.

Brand size		Legibility (%)		
Line width	Height	Legible	Partly Legible	Illegible
Steelhead				
3/64"	3/16"	47	30	23
1/16"	3/8"	81	12	7
Chinook				
3/64"	3/16"	38	22	40
3/64"	1/4"	82	15	3

They had four suggestions that they felt would aid in controlling much of the variability formerly observed in the quality of cold brands. Three of the four factors generally agreed with our findings: type of brand, application time, and location. The fourth suggestion on changes in hue is worth passing on: "Changes in hue occurred in both dead and live fish, and significantly affected the readability of brands. Fish with unreadable or poor quality brands should be placed in holding containers that will stimulate a maximum change in hue and the brands reexamined. Fish captured by fishermen should be examined for marks at the time of capture, before being creeled."

Although Raleigh et al. (1973) appear to have resolved some of the problems associated with branding trout and bass, we still have not perfected branding on anadromous salmon and steelhead trout. Much still needs to be learned about the effect of differences in size, condition, and age of fish, differences between smolting and nonsmolting fish, variability among fish markers, etc., on brand retention. Park and others, I feel, are on the right track in emphasizing increased brand size on smolt-size fish.

To date much of our knowledge on salmon branding has come from experiments designed to obtain information on aspects other than fish marking. What is really needed is a series of controlled experiments on various sizes and species of salmon and steelhead trout, carried out for a sufficient period of time. On the basis of knowledge at hand, we can suggest a series of experiments in an attempt to standardize the methodology required to affix a permanent brand on salmon and steelhead trout.

A salmon and steelhead hatchery where returns to the hatchery could be examined immediately on arrival should be selected. A series of controlled experiments could be run, testing the effect of the following on clarity and retention of brands:

(1) Relation of fish size to application time and size of brand.

(2) Relation between time of year, degree of smoltification, scale development, and condition (feeding, nonfeeding) of fish at time of marking.

(3) Variation among different species and sizes of fish.

(4) Symbols—which brand configuration should be eliminated?

(5) Differences in methods of heat transfer—boiling water, dry ice and alcohol, liquid nitrogen, freon.

(6) Compare tissue sections taken in branded area of fish for each variable at time of marking and on adult returns.

(7) Time and pressures of application—as mentioned previously, this aspect could be the most important of all.

An experiment I have in mind would involve a test group of fish marked with six markers, each with a different brand, marking as before without any control other than holding the brand on the fish for about 1 second. Returns could be compared with returns from another test group

marked with a machine (presently being engineered) that maintains constant pressure and application time. These results could provide considerable insight into the degree that differences in fish markers play on variability in brand retention.

These are only a few of the areas where research is needed on fish branding. Concurrent experiments with centrarchids could be conducted in other areas of the country. I feel that graduate students in fisheries schools could do the research. If properly designed and executed, the results of the research would provide suitable thesis material.

LITERATURE CITED

Buss, K. 1961. There's more than one way to leave a mark on life. Pa. Angler 30(10):2-5.

Ebel, W. J. 1974. Marking fishes and invertebrates III. Coded wire tags useful in automatic recovery of chinook salmon and steelhead trout. Mar. Fish. Rev. 36(7):10-13.

Ebel, W. J., D. L. Park, and R. C. Johnsen. 1973. Effects of transportation on survival and homing of Snake River chinook salmon and steelhead trout. Fish. Bull., U.S. 71:549-563.

Everest, F. H., and E. H. Edmundson. 1967. Cold branding for field use in marking juvenile salmonids. Prog. Fish-Cult. 29:175-176.

Fujihara, M. P., and R. E. Nakatani. 1967. Cold and mild heat marking of fish. Prog. Fish-Cult. 29:172-174.

Groves, A. B., and I. W. Jones. 1969. Permanent thermal branding of coho salmon. *Oncorhynchus kisutch*. Trans. Am. Fish Soc. 98:334-335.

Groves, A. B., and A. J. Novotny. 1965. A thermal-marking technique for juvenile salmonids. Trans. Am. Fish. Soc. 94:386-389.

Jefferts, K. B., P. K. Bergman, and H. F. Fiscus. 1963. A coded wire identification system for macro-organisms. Nature (Lond.) 198:460-462.

Johnson, D. E., and P. E. Fields. 1959. The effectiveness of an electric hot-wire branding technique for marking steelhead fingerling steelhead trout. Univ. Wash., Coll. Fish., Tech. Rep. 47, 4 p.

Mighell, J. L. 1969. Rapid cold-branding of salmon and trout with liquid nitrogen. J. Fish. Res. Board Can. 26:2765-2769.

Raleigh, R. F., J. B. McLaren, and D. R. Graff. 1973. Effects of topical location, branding techniques and changes in hue on recognition of cold brands in centrarchid and salmonid fish. Trans. Am. Fish. Soc. 102:637-641.

Schoeneman, D. E., R. T. Pressey, and C. O. Junge, Jr. 1961. Mortalities of downstream migrant salmon at McNary Dam. Trans. Am. Fish. Soc. 90:58-72.

Smith, J. R. 1973. Branding chinook, coho, and sockeye salmon fry with hot and cold metal tools. Prog. Fish-Cult. 35:94-96.

Watson, J. E. 1961. The branding of sea herring as a short-term mark. Prog. Fish-Cult. 23:105.

Weber, D., and R. J. Wahle. 1969. Effect of finclipping on survival of sockeye salmon (*Oncorhynchus nerka*). J. Fish. Res. Board Can. 26:1263-1271.

Worlund, D. D., R. J. Wahle, and P. D. Zimmer. 1969. Contribution of Columbia River hatcheries to harvest of fall chinook salmon (*Oncorhynchus tshawytscha*). U.S. Fish Wildl. Serv., Fish. Bull. 67:361-391.

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MFR PAPER 1068

Large and simple letters result in long-term brand retention.

Marking Fishes and Invertebrates. II. Brand Size and Configuration in Relation to Long-Term Retention on Steelhead Trout and Chinook Salmon

DONN L. PARK and WESLEY J. EBEL

INTRODUCTION

Cold-branding techniques have been used successfully by fishery researchers to place marks on many species of fish. Mighell (1969) reported using liquid nitrogen as a coolant to place a visible short-term brand on chinook salmon, *Oncorhynchus tshawytscha*, and steelhead trout, *Salmo gairdneri*, as an identifying mark during freshwater life. Until recently, however, little information has been available on the successful use of cold branding for producing long-term marks, i.e., marks recognizable on adult salmonids returning from the ocean one or more years after having been branded as smolts.

Early evidence that brands placed on juvenile salmonids would be retained to the adult stage was recorded by the Fish Commission of Oregon (Groves and Jones, 1969). They found a number of recognizable brands on returning adult coho salmon, *O. kisutch*. In the early fall of 1970, Washington Department of Game personnel observed adult steelhead trout with large brands as the fish passed a viewing window in the fish ladder of Little Goose Dam on the Snake River.[1] These fish were returnees from a study group that had been branded and released in the spring of 1969 as smolts in the Grande Ronde River, a tributary of the Snake River. Size of brand symbols used in this instance was larger than on any previous occasion. The obvious legibility of the brand used by Washington State indicated that brand size might be a significant factor in determining long-term legibility.

Ebel, Park, and Johnsen (1973) subsequently reported on brand legibility of adult chinook salmon and steelhead trout returning to the Snake River from transportation experiments at Ice Harbor Dam in 1968. Some of these data obtained during 1970-71 are presented to provide a baseline comparison of the large brands we tested in 1971-72.

Realizing that long-term brands could be placed on juvenile salmonids and that brand size might be the key to long-term retention, we began experimenting with various sizes and configurations of brands. The results of these tests are presented in this paper.

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[1] Pers. comm. Anthony Eldred, Washington Department of Game, Moses Lake, Washington.

METHODS

Juvenile spring and summer chinook salmon and steelhead smolts migrating downstream in the Snake River were obtained for branding at Ice Harbor Dam during 1968-70 and at Little Goose Dam during 1971-72. Size range of the chinook was 80-150 mm and that of steelhead 160-250 mm. The cold-branding technique described by Mighell (1969), where liquid nitrogen was used as the coolant, was utilized throughout the experiment. He specified an application time of 1-1.5 seconds for brands about $^3/_{16} \times {}^3/_{16}$ inch. We adhered to this application time during 1968-70 but, in 1971-72 when we increased the size of the brand, we reduced the application time to 0.5-1.0 seconds. The pressure applied to the brand was not measured. Application pressure, however, was kept below the level where descaling or injury might occur.

From 1968 through 1970, chinook and steelhead were branded with the same brand symbols that were $^3/_{16}$ inch high and approximately $^3/_{16}$ inch wide, depending on the symbol used. The line width was $^3/_{64}$ inch. In 1971-72, a symbol ¼ inch high and about ¼ inch wide was used on chinook. The thickness of the lines remained the same in 1968-71 but was increased to $^1/_{16}$ inch in 1972. The symbol used for steelhead in 1971-72 was ⅜ × ⅜ inch. The line thickness was increased slightly in 1972 to $^3/_{32}$ inch from $^1/_{16}$ inch in 1971. A complete range of branding symbols with details on size is presented in Figure 1 for comparison.

The ⅜- × ⅜-inch-high brand was considered maximum for steelhead. A larger brand could not be effectively placed on the smaller fish within the population size range. Similarly, ¼-inch-high brands were near maximum height for chinook. We avoided placement of the brand on the lateral line.

Many brand configurations (symbols) were used. A partial list included group 1: IK, IF, IL, and IH; group 2: F, H, K, W, and T; and group 3: IL, IH, IK, IN, and IT. Group 1

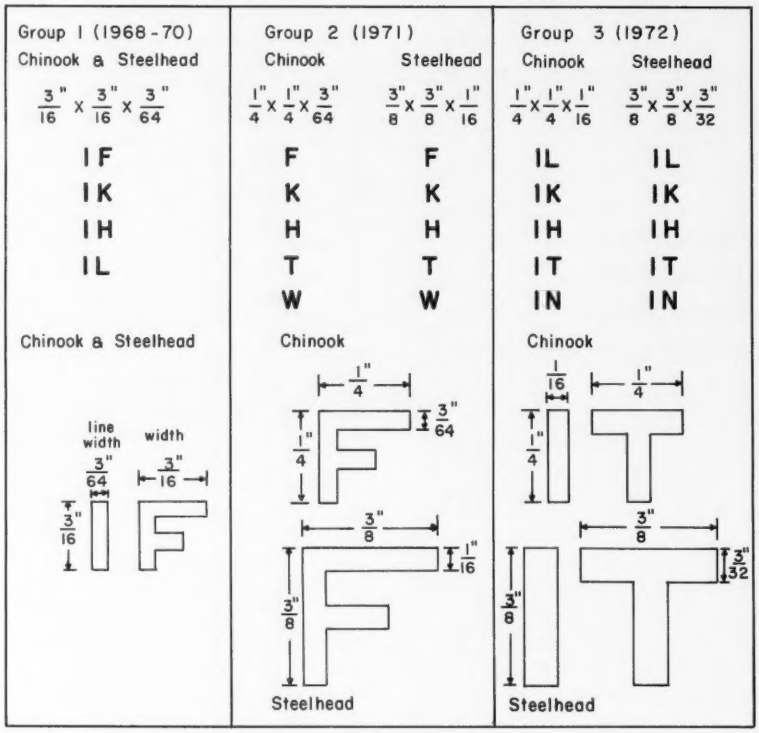

Figure 1.—Examples of brand configurations used in branding studies 1968-72 (upper section). Brands identifying dimensions and comparative sizes (lower section).

brands were used during the 1968-70 experiments, group 2 in 1971, and group 3 in 1972. After branding, the fish were released into the river at various locations where they completed their seaward migration. In addition to being branded, the adipose was excised and a minute magnetic wire tag (Jefferts, Bergman, and Fiscus, 1963) was injected into the snout. The magnetic wire provided the means for collection (Ebel et al., 1973); the adipose clip provided visual identification of test fish regardless of brand legibility. Upon their return from the ocean, adult migrants were intercepted as they ascended the fish ladder at Ice Harbor Dam (prior to 1972) or at Little Goose Dam (1972-73). Upon interception, adults were anesthetized and examined critically for brand retention.

Retention of brands was categorized as: (a) legible, (b) partly legible, or (c) illegible. A legible brand was complete even though faint; a partly legible brand could not be positively identified as to symbol or the symbol was partly missing. Complete loss of the brand was termed illegible.

RESULTS

Among returns of fish marked in 1968-72, legibility was determined for 1,706 adult steelhead and 582 spring and summer run chinook salmon (Table 1). Group 2 and group 3 type symbols clearly produced the most legible long-term brands. Group 3 brands were retained on steelhead slightly better than were the group 2 brands. The reverse was indicated for chinook. The authors and others recording legibility of brands unanimously favored the group 2 symbols for both species. The double-symbol brand used in group 3, because of the large size and numerous lines, caused some lines to be more faintly imprinted. This was especially true on the smaller chinook, and errors in reading were increased.

In general, symbols with the simplest lines and fewest angles produced the sharpest brands (Fig. 2). Among the 1-ocean steelhead, the F and T (Fig. 3) appeared most effective and the W least effective among group 2 brands in producing desired long-term retention. Conversely, four of the brand symbols (including the W) were more legible on steelhead returning after 2 years at sea than they were after 1 year at sea. This phenomenon is unexplained at this time. When the data on legibility of 1- and 2-ocean steelhead are combined and averaged, the differences among legibility of group 2 brands is reduced. Legibility ranges from a low of 87 percent for the W symbol to 95 percent for the

Table 1.—Brand legibility (percentage of group 1-, 2-, and 3-type brands) as retained on adult steelhead trout and chinook salmon. (All fish were marked at time of downstream migration.)

Species	Year marked	Brand group	Ocean age at year of return	Number of returns	Legibility (%)		
					Legible	Partly legible	Illegible
Steelhead	1969	1	1	115	64	12	24
Steelhead	1970	1	2	283	47	30	23
Steelhead	1971	2	1	425	80	11	9
Steelhead	1971	2	2	496	80	14	6
Steelhead	1972	3	1	387	91	7	2
Chinook	1968	1	2	212	38	22	40
Chinook	1968	1	3	109	15	18	67
Chinook	1971	2	1	48	96	0	4
Chinook	1971	2	2	194	82	14	4
Chinook	1972	3	1	19	63	31	6

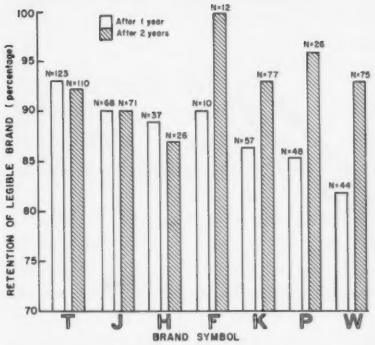

Figure 2.—Percentage of brands (group 2) retained in legible condition on steelhead trout marked during smolting migration, returning after 1 and 2 yr at sea.

F symbol. Returns of 2-ocean steelhead and chinook branded in 1972 are expected in 1974, so comparisons between legibility of brands on these fish and the 1-ocean group await that return. We want to stress that the data contained in Figure 2 do not include illegible brands. The origin of illegible brands could not be determined without sacrificing the fish.

Finally, application techniques must be considered in any branding effort. A steady hand that does not smear the brand is required, and application time must be controlled as well as possible. Brands applied too long destroy tissue and cause a wound that later heals and obliterates the configuration. A brand applied too quickly also becomes illegible.

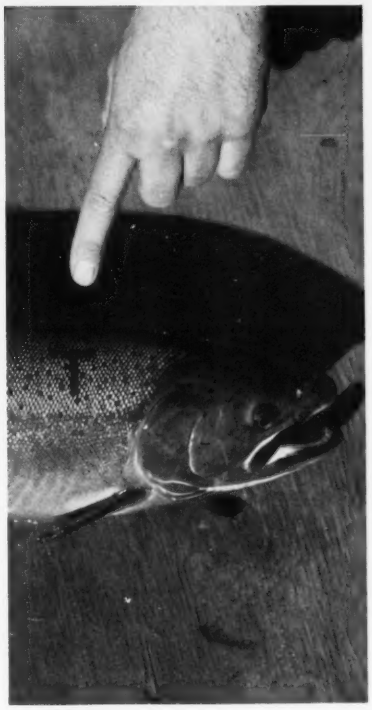

Figure 3.—One-ocean steelhead trout with group 2 type brand that was placed on the fish during its downstream migration as a juvenile.

Although we did not measure the pressure applied to our brands, it may be important to the ultimate legibility of the brand. Data obtained by the authors and others in similar experiments indicated that variations in pressure as well as variations in application time could affect brand legibility. Further testing is needed to remove these variables from the branding operation. The correct combination of brand symbol, size of symbol, application time, and pressure could probably result in 100 percent legibility and retention on juvenile spring and summer chinook salmon and steelhead trout of smolt size.

LITERATURE CITED

Ebel, W. J., D. L. Park, and R. C. Johnsen. 1973. Effects of transportation on survival and homing of Snake River chinook salmon and steelhead trout. Fish. Bull., U.S. 71:549-563.

Groves, A. B., and I. W. Jones. 1969. Permanent thermal branding of coho salmon, *Oncorhynchus kisutch*, Trans. Am. Fish. Soc. 98:334-335.

Jefferts, K. B., P. K. Bergman, and H. F. Fiscus. 1963. A coded wire identification system for macro-organisms. Nature (Lond.) 198:460-462.

Mighell, J. L. 1969. Rapid cold-branding of salmon and trout with liquid nitrogen. J. Fish. Res. Board Can. 26:2765-2769.

MFR Paper 1068. From Marine Fisheries Review, *Vol. 36, No. 7, July 1974. Copies of this paper, in limited numbers, are available from D83, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235.*

MFR PAPER 1069

Coded wire tagging is excellent for automatic identification.

Marking Fishes and Invertebrates. III. Coded Wire Tags Useful in Automatic Recovery of Chinook Salmon and Steelhead Trout

WESLEY J. EBEL

ABSTRACT

The successful use of the coded wire tag (1 × 0.25 mm, placed in snout) for marking of juvenile Pacific salmon (Oncorhynchus *spp.) and steelhead trout* (Salmo gairdneri) *migrating downstream in the Snake River is described. Problems associated with tagging and with detection of tags in adult fish previously marked as smolts are discussed. General descriptions of the automatic tag detector and adult fish separator are given.*

INTRODUCTION

The problem of marking or tagging juvenile salmon and trout for later identification as adults has perplexed fishery biologists for years. The most common method has been to excise one or more fins. This procedure often results in problems of excessive stress and disease—or sometimes in changed behavior and growth (Bergman et al., 1968). Moreover, fin-clipping of experimental groups of fish does not allow more than two comparably marked groups. Experiments that require comparison among several experimental groups cannot be conducted without bias as one or more of the experimental groups will have additional or different fins removed.

The use of thermal marks (hot and cold) on juvenile Pacific salmon, *Oncorhynchus* spp., and steelhead trout, *Salmo gairdneri*, for later identification as adults has been described by Groves and Jones (1969) and by Ebel, Park, and Johnsen (1973). Their data indicated that cold branding has considerable potential as a versatile form of marking certain species and size ranges. However, the optimum technique for use on a given species and size range is still in the process of evaluation.

A promising method for long-term marks appears to be the coded wire identification system developed by Jefferts, Bergman, and Fiscus (1963). It was further evaluated by Bergman et al. (1968) and by Hager and Jewell (1968). Many of the disadvantages associated with fin-clipping are eliminated, and an almost unlimited number (10^6) of experimental groups can be identified. This system, of course, is not without fault. Problems with tag loss, malfunction of the tagging gear, and later detection of the tags on adult fish are some of them, but recent refinements of the injectors, detectors, and mark and recovery methods in the field have eliminated most of the problems. Initial cost of equipment is relatively high, however, which can be a disadvantage.

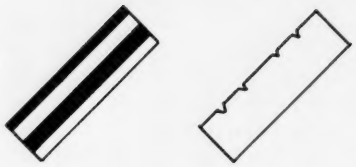

Figure 1.—Magnified binary and color coded wire tags (actual size 1 × 0.25 mm).

At present two types of commercially available tag injectors and two types of wire (binary and color coded, Fig. 1) are available. Detection systems for recovery also are available from two commercial firms.

We recognized the potential of the magnetized wire tag for automatic detection and separation of tagged adult salmon. A system, or device, that would detect and separate tagged from untagged fish was needed in evaluating our experiments on transportation of juvenile fish past hazardous areas. We developed an automatic system with the assistance of Dr. Keith Jefferts and other personnel of the Technical Research Company, Seattle, Washington.[1] This sytem was successfully operated in fish ladders on the Snake River at Ice Harbor and Little Goose Dams from 1970 to the present. Ice Harbor is in Washington State near the confluence of the Snake and Columbia Rivers; Little Goose is approximately 65 miles upstream.

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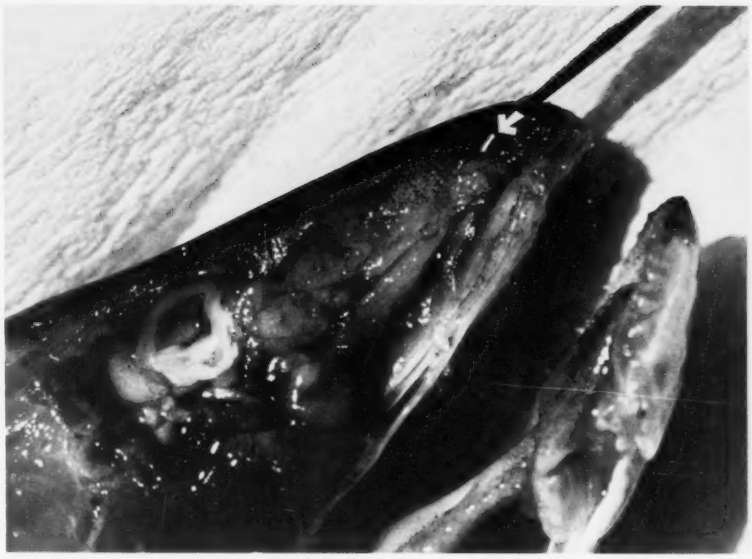
[1]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Figure 2.—Cross section of juvenile chinook salmon showing placement of coded wire tag.



CODED WIRE TAG USED IN MARKING NATURALLY MIGRATING JUVENILE SALMONIDS

Use of the wire tag for marking salmonids was formerly limited to hatchery stocks. To evaluate our experiments on the Snake River, it was necessary to mark naturally migrating hatchery or wild juvenile spring and summer chinook salmon, *O. tshawytscha*, and steelhead trout. We soon found that marking of these stocks of primarily wild fish with wire tags presented unusual problems. Juvenile salmon and steelhead migrating in the lower Snake River consist of many races. Consequently there is wide diversity in size range of the migrants, depending on the time that one wishes to sample the population. Our project was ambitious. We wished to mark samples from all stocks or races. For a successful tagging operation, correct placement of the tag was highly critical. Bergman et al. (1968) found that the best area for inserting the tag was the cartilaginous wedge of the chondrocranium located in the snout anterior to the eyes (Fig. 2).

Since we were attempting to mark two species of fish with a wide range of sizes, it was necessary to construct a facility where fish could be conveniently sorted by size and species and routed to an injector with a head mold of appropriate size for accurate placement of the tag (Fig. 3).

Both mobile and stationary facilities (Fig. 4) were constructed where large samples of juvenile fish could be held, anesthetized, and sorted. These facilities have worked well. Tagging techniques have been refined to the point where initial tag loss (determined by checking several days after tagging) is less than 1 percent. In 3 successive years of tagging from 1968 to 1970, initial tag loss was 9.2, 5.0, and 1 percent. Tag loss from fish now being marked at Little Goose Dam has been less than 1 percent.

Overall tag loss (from time of tagging to return of adults) was obtainable from those marked in 1968 when 9.2 percent initial tag loss was recorded. Overall tag loss was 27 percent from that year's marking. We attributed this high tag loss primarily to poor placement of the tag because of inexperienced taggers. Lack of refinement of the earlier tag injectors and head molds also contributed to this tag loss. Overall tag loss was not obtainable in 1969-70 because of lack of sufficient returns. At Little Goose, recent overall tag loss was 3 percent.

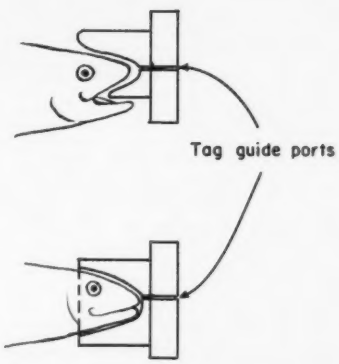


Figure 3.—Open (top) and closed-type (bottom) head molds used in positioning head of fish for wire tagging.

Figure 4.—Inside of marking building showing sorting area and tagging locations.

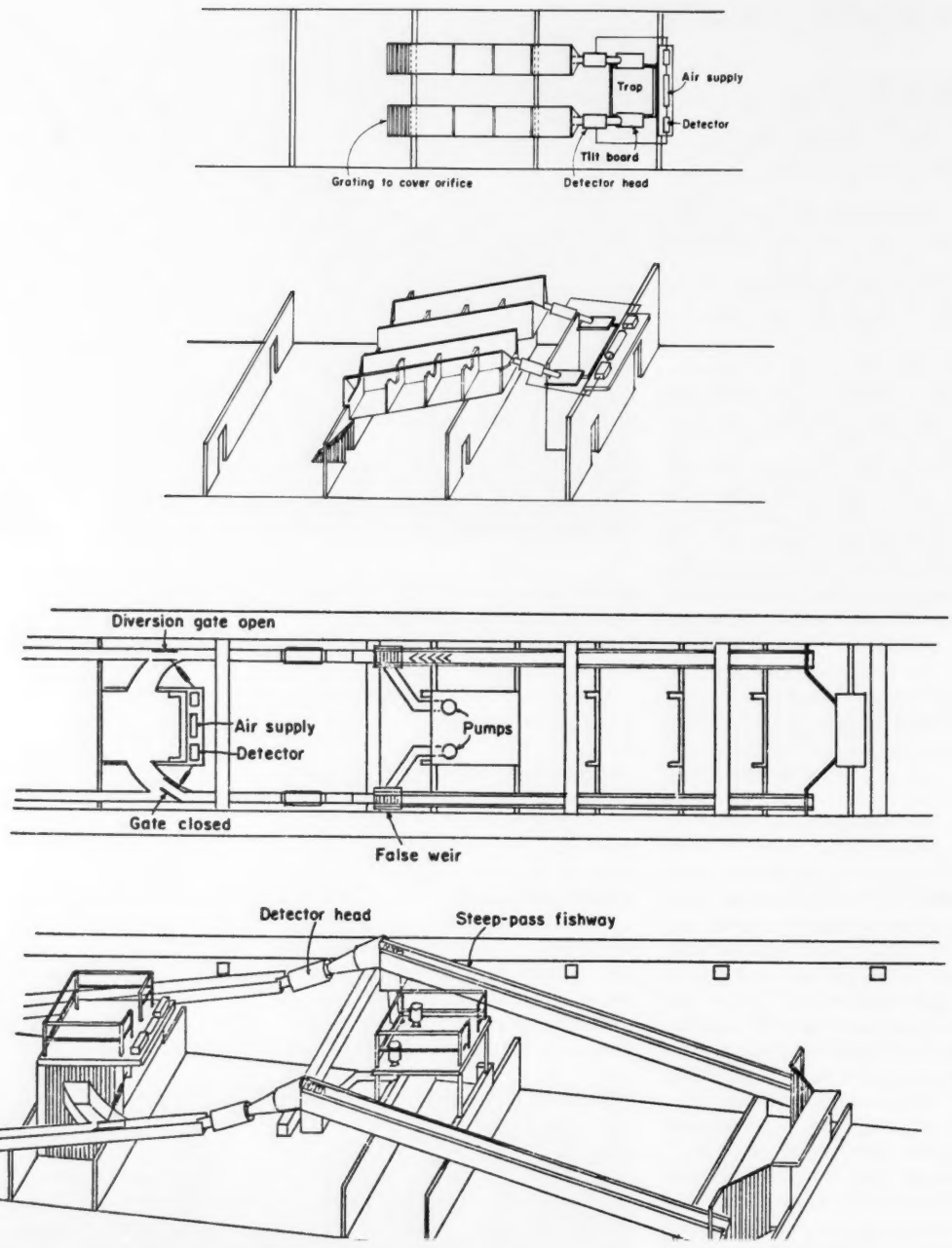


Figure 5.—Plan views and isometric diagrams of wire tag detector and fish separator systems used at Ice Harbor Dam (upper) and Little Goose Dam (lower).

Thus, we conclude that coded wire tagging is an excellent method of marking naturally migrating as well as hatchery stocks of Pacific salmon and steelhead trout.

ADULTS DETECTED AND SEPARATED AUTOMATICALLY

As indicated earlier, our primary interest in using the coded wire tag was because of its potential for automatic detection and recovery of naturally migrating adult chinook and steelhead ascending fish ladders. Such a system was needed to evaluate the results of experiments in which we transported juvenile fish past barrier dams during their migration downstream.

In 1966, when we first began investigating the possibility of using the wire tag for rapid automatic detection and separation, no detection system had been designed that could accomplish the objective. Available detection equipment was designed for use on dead fish recovered either in the fishery or at the hatcheries.

Preliminary studies (Durkin, Ebel, and Smith, 1969) at the Fisheries-Engineering Research Laboratory of the U.S. Army Corps of Engineers, Bonneville Dam, and at the Minter Creek Hatchery of the Washington Department of Fisheries near Purdy indicated that a system utilizing a hollow cylindrical detection coil located where fish would pass through at a speed of 0.6 mps or greater could be used.

Attempts to devise a system where the fish would swim through the detector coil were unsuccessful as the fish moved too slowly to induce sufficient current for detection. The detector proved satisfactory, however, when taken out of the water and used in a fish ladder where fish jumped over a false weir and slid down a chute past the detector. This movement was rapid enough to induce sufficient current for detection.

A prototype system was built and installed at Ice Harbor Dam in 1970 (Fig. 5) for use in detecting and examining adult fish, tagged as juveniles in 1968. This system was successful in automatic detection and separation of about 300 tagged adult spring and summer chinook from a run of about 30,000 fish that passed through the unit.

The need for several improvements was indicated, however. The tilt board did not always direct the fish accurately into the trap. The overfall-type ladder placed within the existing ladder at Ice Harbor caused some delay in passage of the migration, which forced us to take the system out of operation during the peak of the run.

An improved design of the Ice Harbor type system (Fig. 5) was installed at Little Goose Dam in 1971. This system used a Denil-type ladder instead of the overfall weir-type and eliminated all problems in delay of passage. A gate-type diversion chute replaced the tilt board which eliminated the escape of fish encountered with the Ice Harbor trap.

The electronic circuitry was modified slightly to include a counter for enumeration of tagged fish. A power supply was also built to replace the detector batteries normally used in the detectors, and additional circuits were added to the detectors to eliminate excess sensitivity to outside signals. This unit operated very well in 1972-73 and permitted detection and separation of over 1,500 tagged fish from the migrations passing up the ladder at Little Goose Dam. Although data on exact efficiency of the unit are incomplete at this time, a preliminary estimate indicates that at least 70 percent of all tagged fish passing up the ladder were successfully detected and separated.

The unit was also used to assist other organizations in their investigations. For example, data from over 1,000 adult salmon carrying magnetized spaghetti tags were recovered and relayed to the Fish Commission of Oregon.

CONCLUSION

We concluded that use of the wire tag for marking both hatchery and naturally migrating juvenile salmon and trout is superior to other methods such as fin-clipping or branding if automatic separation and positive identification are required.

LITERATURE CITED

Bergman, P. K., K. B. Jefferts, H. F. Fiscus, and R. C. Hager. 1968. A preliminary evaluation of an implanted, coded wire fish tag. Wash. Dep. Fish., Fish. Res. Pap. 3(1):63-84.

Durkin, J. T., W. J. Ebel, and J. R. Smith. 1969. A device to detect magnetized wire tags in migrating adult coho salmon. J. Fish. Res. Board Can. 26: 3083-3088.

Ebel, W. J., D. L. Park, and R. C. Johnsen. 1973. Effects of transportation on survival and homing of Snake River chinook salmon and steelhead trout. Fish. Bull., U.S. 71:549-563.

Groves, A. B., and I. W. Jones. 1969. Permanent thermal branding of coho salmon, *Oncorhynchus kisutch*. Trans. Am. Fish. Soc. 98:334-335.

Hager, R. C., and E. D. Jewell. 1968. Field evaluation of coded wire tag detection and recovery techniques. Wash. State Dep. Fish., Res. Div., Suppl. Prog. Rep., Mar. Fish. Res. Manage., Coded Wire Tag Invest. 20 p.

Jefferts, K. B., P. K. Bergman, and H. F. Fiscus. 1963. A coded wire identification system for macro-organisms. Nature (Lond.) 198:460-462.

MFR Paper 1069. From Marine Fisheries Review, *Vol. 36, No. 7, July 1974. Copies of this paper, in limited numbers, are available from D83, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235.*

MFR PAPER 1070

Anchor tags show merit for short-term crab marking and recapture experiments.

Marking Fishes and Invertebrates. IV. A Nonpermanent Tag for King Crabs, *Paralithodes camtschatica*, and Tanner Crabs, *Chionoecetes bairdi*

ROBERT M. MEYER

ABSTRACT

The National Marine Fisheries Service had need of an easily applied, short-term tag for marking king crabs, Paralithodes camtschatica, *and Tanner crabs,* Chionoecetes bairdi. *A Floy anchor tag system was evaluated using 72 king crabs held in two 6- × 6-ft king crab pots and two Tanner crabs held in an aquarium. Tags were easily applied even under severe weather conditions and were retained up to 125 days. Damage to the animals was minimal as indicated by autopsies, showing the tag isolated between the carapace and underlying tissues.*

INTRODUCTION

Kodiak Investigations personnel of the Northwest Fisheries Center, National Marine Fisheries Service (NMFS), had need of an easily applied tag for marking king crabs, *Paralithodes camtschatica*, and Tanner crabs, *Chionoecetes bairdi*. Demands of the marking program required that the tag provide identification of each crab, have a high retention rate, be nonlethal, and quick to apply. The recently developed Floy anchor tagging system[1] described by Thorson (1967) and Dell (1968) appeared to meet these qualifications. A study was initiated to test the efficiency of the anchor tag on king crabs under field conditions and on Tanner crabs in an aquarium.

[1]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

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MATERIAL AND METHODS

Seventy-two adult king crabs (including 36 tagged and 36 controls) were placed in two 6- × 6-ft × 34-inch king crab pots. The pots, their tunnel entrances closed with hand sewn nylon netting, were set in approximately 50 ft of water in Dog Bay, Saint Paul Harbor, Alaska. Two adult male Tanner crabs were also tagged and retained in an aquarium at Gibson Cove near Kodiak, Alaska.

At weekly intervals, the pots were examined by divers who recorded the number of live and dead crabs. After 125 days the remaining crabs were removed and the number of tagged and untagged crabs and the condition of each carapace at the point of tag insertion recorded. Three crabs were

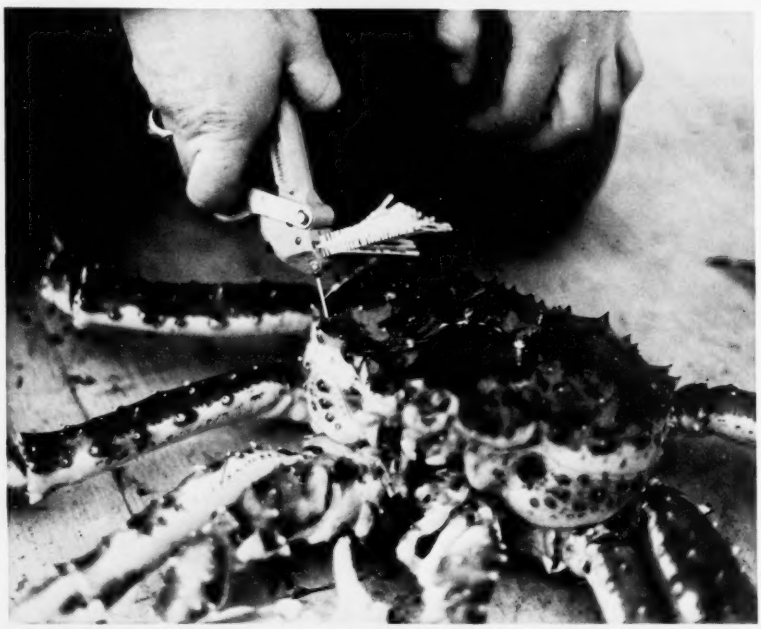


Figure 1.—Anchor tag being inserted into shoulder of king crab.

retained for examination of internal tagging scars.

The crabs were tagged on the right anterior side of the carapace (Fig. 1) at the base of the first prominent spine or between the base of the first and second prominent spines. The T bar portion of the tag was inserted through the carapace into the anterior portion of the right branchial cavity. The anchor portion of the tag often failed to return to its normal shape after insertion. Care was taken, therefore, to insure that the T bar was pulled tight against the ventral surface of the carapace and at right angles to the tag shaft. Properly tagged king and Tanner crabs, ready for release, are shown in Figure 2.

RESULTS

Tagging under even the severe conditions of 10°F (−12°C) with 15-25 mile per hour winds was accomplished with ease, requiring only 10-15 seconds to tag each crab. Occasionally the hardness of a crab carapace caused the spring driving the tag ejector piston to buckle; however, this resulted in little delay of the tagging operations.

As shown in Table 1, 37 crabs remained in the pots after 125 days. Only five known mortalities were observed during the 125-day period. These consisted of one tagged and two untagged crabs within the pots and two crabs trapped beneath the pots. Because of poor visibility, divers were unable to determine if the crabs trapped under the pot were tagged or untagged. The crabs were assumed to have escaped through the netting in the bottom of the pot, since the pot frame had settled several inches into the substratum and there was no evidence of crabs having burrowed under the pot frame.

Table 1.—Number of tagged and untagged king crabs held in pots for 125 days.

Experimental group	Sex	Initial number of crabs	Final number of crabs	Percentage retained
Tagged	Male	25	13	52
	Female	11	1	9
Untagged	Male	31	21	68
	Female	5	2	40
Total		72	37	51

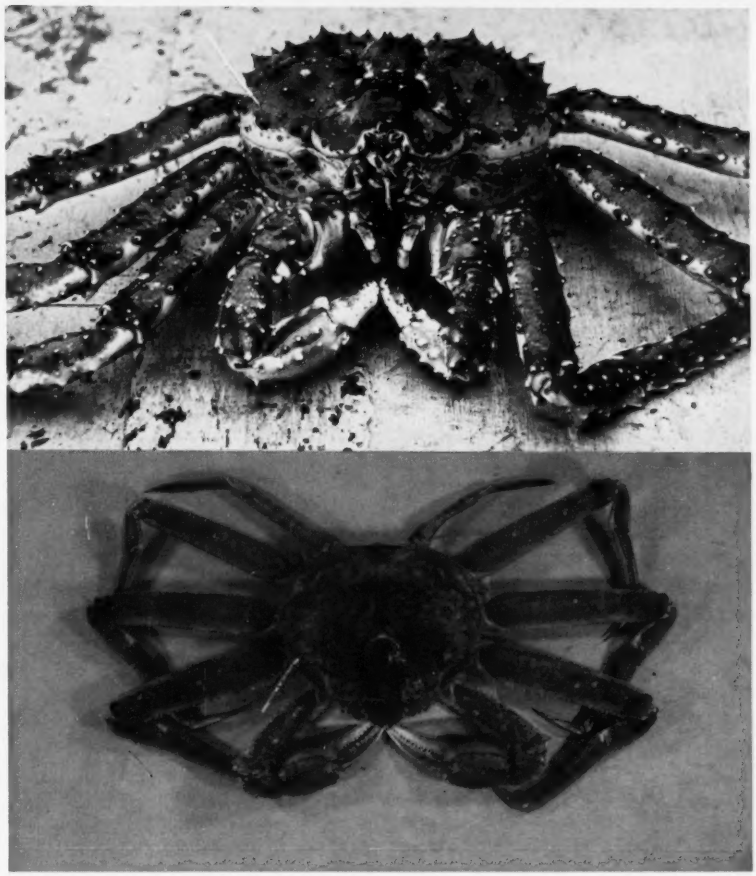


Figure 2.—Tagged king crab (upper photo) and tagged Tanner crab (lower photo) ready for release.

At the conclusion of the study the external tag scar of each of the remaining 14 tagged crabs was examined. Scars consisted of a hole ¼-⅜ inch in diameter surrounded by a blackened ridge ⅛ inch in thickness. In only one case was the hole large enough to allow removal of the tag.

Three king crabs were sacrificed and their internal tag scars examined. Soft tissues lining the ventral surface of the carapace showed no sign of infection, and the T bar had been isolated between the hard part of the carapace and the soft underlying tissue. On one crab, which was approaching ecdysis, the T bar was between the old shell and the underlying new shell, indicating the tag would have been lost at ecdysis.

Although controls were insufficient to determine total tag-induced mortalities, those caused by infection because of the T bar being lodged between the carapace and soft underlying tissue were assumed to be low.

The two tagged Tanner crabs held in the aquarium were sacrificed after 3 weeks and their tag scars examined. Scars and tissue condition found in the Tanner crabs were similar to those found in the king crabs. Scar tissues in the Tanner crabs, however, were not as well developed as those in the king crabs.

DISCUSSION

The 4- to 5-inch (stretched mesh) hand sewn netting used to close crab pot tunnels was prone to slippage. Frequent manipulation of the netting by the captured crabs could have caused netting knots to slip, resulting in a hole large enough to allow them to escape. The total number of crabs in the pots decreased from 72 to approximately 41 after 2 weeks and to 37 after 125 days.

The disproportionate loss of tagged female crabs from the pots may have been due to increased mortality of those tagged. This seems unlikely, however, since only five mortalities were actually observed, suggesting that the crabs were indeed escaping from the pots. Female crabs are generally smaller than male crabs (Gray, 1963), which could increase their chances of working their way through the tunnel closures. Irritation from the tags may induce molting, and soft, freshly molted crabs may be more capable of escaping through pot netting.

Predation and cannibalism are two other possible causes for the reduction of the number of crabs in the pots. No evidence of these activities was observed in the pots, however.

The Floy anchor tag has also been used on crabs in various other studies. It was used successfully, for example, in a short-term tagging program involving Tanner crabs.[2] The study was conducted during the fall and winter of 1971 in Larson Bay on the northwest side of Kodiak Island. A total of 1,894 crabs was tagged and 102 were recovered, of which 27 had been at large for over 90 days. That the tags can be carried for extended periods with little apparent damage to the crab, is indicated by the preliminary results of a study conducted by the author which involved the tagging (with anchor tags) and release of 330 king and 25 Tanner crabs in a commercial fishing area. Nineteen of the king crabs were returned from the commercial fishery; five had been at large for approximately 335 days and one for approximately 660 days. Discoloration of tags, a problem reported by Chadwick (1963) who used dart tags of Resinite to mark striped bass, *Morona saxatilis*, was minimal in this study. The vinyl tubing section of the anchor tag showed little discoloration after 335 days. The tag which had been at large for 660 days was not examined by the author, but the fishing vessel captain who recovered the tag reported that it was legible and exhibited little discoloration.

The inexplicable loss of crabs from the control pots leaves the question of tag shedding and tag-induced mortality unanswered. This problem should be resolved by additional experiments. The recovery of a number of tagged animals, some of which had been at large for nearly a year, indicates that this tagging method has merit and would be suitable for short-term mark and recapture experiments.

[2] Pers. comm., G. M. Reid, NMFS Kodiak Laboratory, Kodiak, Alaska 99615.

LITERATURE CITED

Chadwick, H. K. 1963. An evaluation of five tag types used in a striped bass mortality rate and migration study. Calif. Fish Game 49:64-83.

Dell, M. B. 1968. A new fish tag and rapid, cartridge-fed applicator. Trans. Am. Fish. Soc. 97:57-59.

Gray, G. W., Jr. 1963. Growth of mature female king crabs, *Paralithodes camtchatica* (Tilesius). Alaska Dep. Fish Game, Inf. Leafl. 26, 4 p.

Thorson, K. N. 1967. A new high-speed tagging device. Calif. Fish Game 53: 289-292.

MFR Paper 1070. From Marine Fisheries Review, *Vol. 36, No. 7, July 1974. Copies of this paper, in limited numbers, are available from D83, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235.*

MFR PAPER 1071

Valued for meat and shells, the giant clam faces an increased harvest.

A Survey of Giant Clams, Tridacnidae, on Helen Reef, a Western Pacific Atoll

FRANK J. HESTER and EVERET C. JONES

Frank J. Hester and Everet C. Jones were formerly members of the staff of the Southwest Fisheries Center, National Marine Fisheries Service, NOAA, Honolulu, HI 96812.

ABSTRACT

Transects and areal surveys by swimmers were used to estimate the standing stock of giant clams, Tridacnidae, at Helen Reef, Western Caroline Islands in March 1972. Estimates were Tridacna crocea *3.7* $\times$ 10^6, T. maxima *1.7* $\times$ 10^6, Hippopus hippopus *44.6* $\times$ 10^3, T. derasa *32.8* $\times$ 10^3, *and* T. gigas *49.8* $\times$ 10^3. Tridacna squamosa *was not abundant or was identified as* T. maxima. *Most* T. gigas *and* T. derasa *were large, suggesting low or erratic recruitment.*

INTRODUCTION

The Indo-Pacific family Tridacnidae comprises two genera, *Tridacna* Bruguiére with five species: *Tridacna gigas* (Linné), *T. derasa* (Roding), *T. squamosa* (Lamarck), *T. maxima* (Roding), and *T. crocea* (Lamarck); and the monotypic genus *Hippopus* represented by the species, *Hippopus hippopus* (Linné). Of these six species *T. gigas* is the largest, reaching a valve length in excess of 1,300 mm and a valve weight of over 150 kg. It is this species that is the giant clam, peril to divers and an occasional bird bath or holy water font. The other species are intermediate in size with *T. crocea* being the smallest, having a maximum valve length of about 200 mm. For a description of the family and its biology and distribution see Rosewater, 1965.

All of these clams, except possibly *T. crocea*, are of value both for their meat, which is consumed locally, and for their shells, which are of value as souvenirs and to collectors. *Tridacna gigas*, *T. derasa*, and *H. Hippopus*, the larger species, are particularly sought for their shells, which currently have an ex-vessel value in Koror, Palau Islands of approximately $0.02 per millimeter for specimens over 200 mm. The shells of *T. maxima* and *T. squamosa*, being smaller, are of lesser value but they are in demand for the meats. *Tridacna crocea* is seldom utilized for any purpose.

Because of the value of the shell, as well as the potential value of the meats, and because they occur in countries that are seeking foreign exchange, the larger Tridacnidae face increased fishing pressures that may result in a major reduction of the stocks. Already the size and abundance of *T. gigas* has declined in the central Pacific, parts of the Great Barrier Reef, Indonesia, and the Philippines, probably owing to fishing pressure. In some areas the clams are now protected by law. In others, where these animals are of some importance in trade, protective measures may be necessary; however, there are very limited biological and fishery data available to suggest how stringent or what these measures should be.

John J. Naughton, a fishery biologist, with specimens of Tridacnidae.

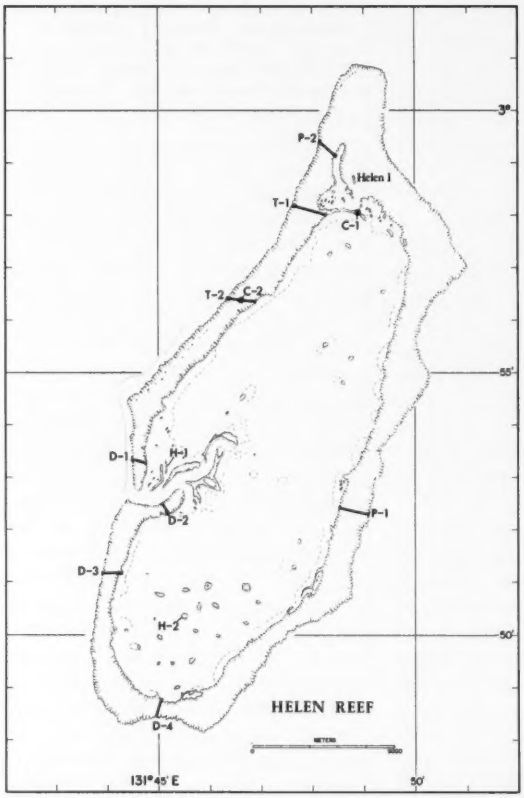


Figure 1.—Helen Reef showing location of transects.

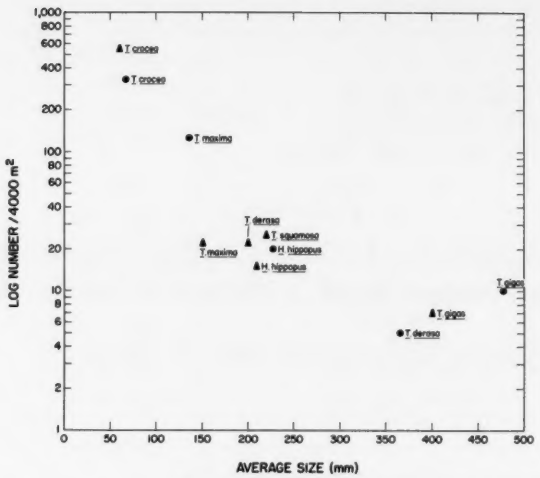


Figure 2.—Average length-frequency data of clams from Helen Reef (circles) and Palau Islands (triangles) (Hardy and Hardy, 1969).

One place that has been reasonably free from exploitation until recently is Helen Reef (Fig. 1), a small atoll to the south-southwest of the Palau Islands in the Palau District, Western Caroline Islands, of the Trust Territory of the Pacific Islands. Helen Reef lies at approximately lat.3°N, long. 131°E. It is about 24 km in its north-south dimension by 9 km in its east-west dimension and consists of reef, awash at high water, and a small sand island with coconut trees and low growth. Situated at the northern end of the reef, the island is about 1 ha (hectare) in area. The reef encloses a large lagoon with depths in excess of 60 m. The reef is about 1,200 m wide except in the north portion, which has an extended sandy area between the lagoon and the sea. A navigable passage on the western side permits access to the lagoon for vessels of moderate draft. Helen Reef lies in an area of variable winds and currents and there is no well-defined windward side although the coral growth is most luxuriant on the west side of the reef. Helen Reef is uninhabited and distant from most population centers and the reef and its associated flora and fauna are nearly untouched, being subject to only occasional visits by Trust Territory field trip ships and foreign fishing vessels. (There have been instances where the latter have been apprehended with *Tridacna* shell and turtles on board —communications from the Office of Marine Resources, Trust Territory of the Pacific Islands.)

In May 1971 and again in March 1972 the research vessel *Townsend Cromwell*, then operated by the Honolulu Laboratory of the National Marine Fisheries Service, Southwest Fisheries Center, called at Helen Reef as part of its marine resource survey of the Trust Territory of the Pacific Islands. On the latter visit of *Townsend Cromwell* a survey of Helen Reef was conducted for the Office of Marine Resources, Trust Territory of the Pacific Islands, in order to obtain a standing stock estimate of the giant clams. This had been requested because of poaching by foreign fishing boats and a growing interest on the part of the Palau District in the development of fisheries there. This report describes that survey and gives an estimate of the status of the stocks for the species found in abundance at the reef.

METHODS

Five types of surveys were used for assessing the *Tridacna* stocks: (1) Line transects: A line marked off at 100-m intervals was stretched normal to the reef from the lagoon to the seaward dropoff. The occurrence of clams within 2½ m on either side of the line was recorded, together with the

Table 1. — Helen Reef survey data.

Sta.	Type and location	Substrate notes	Distribution and abundance				Area surveyed (m^2)	Density clams per 100 m^2	Estimated area both sides of reef transect (ha)	Standing stock estimated numbers
T-1	Linear transect running 285° T from a pipe located at lat. 2°58′00″N, long. 131°48′16″E.	Transect ran from lagoon dropoff (5 m depth) to sea, a distance of 1,500 m. Inner 500 m sand and coral heads (water depth 1.5-2 m) turning to sand; coral and coral rubble 500-1,100 m algal flat and hard reef from 1,100 m to dropoff. The outer 7-800 m is exposed to low water.	*Inner 500 m*	*Mid-500 m*	*Outer 500 m*	*Total*				
			2 *T. gigas*		1 *T. gigas*	3	7,500	0.04	520	2,080
			5 T. derasa	2 T. derasa	1 *T. derasa*	8		0.107		5,500
				2 *H. hippopus*	5 *H. hippopus*	7		0.093		4,853
			T. crocea and *T. maxima* ubiquitous							
T-2	Linear transect running 277° T from a pipe located at lat. 2°56′20″N, long. 131°46′53″E.	Essentially the same as T-1 except transect ended at wrecked freighter 1,100 m from Lagoon across reef. From 300 to 800 m the reef was carpeted with living coral (*Acropora* sp.).	*Inner 300 m*	*Mid-300 m*	*Outer 300 m*	*Total*				
				11 *T. gigas*	5 *T. gigas*	16	5,500	0.29	800	23,273
			2 *T. derasa*	25 *T. Derasa*	6 *T. derasa*	33		0.60		48,000
				1 *H. hippopus*	7 *H. hippopus*	8		0.145		11,636
					1 *T. squamosa*	1				
			T. crocea and *T. maximus* ubiquitous							
C-1	Areal survey of circle 25 m radius around a pipe located at lat. 2°58′03″N, long. 131° 48′56″E.	On shallow finger (2 m depth) of reef extending into lagoon. Massive *Porites* sp. and sand and rubble.	*T. gigas*			4	2,000	0.20	520	10,400
			T. derasa			3		0.15		7,800
			H. hippopus			3		0.15		7,800
			T. maxima			62		3.10		
			T. crocea			200		10.0		
C-2	Areal survey of circle 25 m m radius around a pipe located at lat. 2°56′18″N, long. 131°46′36″E.	On coral carpet midway through T-2.	*T. gigas*			6	2,000	0.30	800	24,000
			T. derasa			2		0.10		8,000
			H. hippopus			13		0.65		52,000
			T. maxima			63		3.15		
			T. crocea			138		6.90		
D-1	Drift transect starting from lat. 2°53′15″N, long. 131°44′45″E. Course 282° T.	Transect ran 600 m across reef of mostly hard coral flat and large rubble.	*T. gigas*			3	3,000	0.10	175	1,750
			T. derasa			4		0.13		2,333
			H. hippopus			6		0.20		3,500
D-2	Drift transect starting from lat. 2°52′18″N, long. 131°45′14″E. Course 330°T.	Transect ran 440 m across sand and coral heads.	No large clams seen				2,200		140	
D-3	Drift transect starting from lat. 2°51′10″N, long. 131°44′16″E. Course 266° T.	Transect ran 700 m from sand and large coral heads to reef flat and rubble. Large *T. gigas* and *T. derasa* along lagoon in 2-3 m water. Power tows made between D-3 and D-4.	*T. gigas*			3	3,500	0.086	430	3,686
			T. derasa			3		0.086		3,686
			H. hippopus			4		0.114		4,914
D-4	Drift transect starting from lat. 2° 48′ 46″ N, long. 131° 45′ 06″ E. Course 200° T.	Transect ran through dirty water 820 m across sand and mostly dead coral. Large clams along lagoon and first 200 m of transect. Power tows made between D-4 and P-1.	*T. gigas*			2	4,100	0.049	550	2,683
			T. derasa			3		0.073		4,024
			H. hippopus			5		0.122		6,707
P-1	Transect under power from lat. 2°52′25″N, long. 131°48′30″E. Course 100° T.	Transect ran 1,200 m. Clams along lagoon in *Acropora* sp. rubble, some signs of *Acanthaster* at work. Few clams on reef except for sandy areas seen on power tows made between P-1 and P-2.	*T. gigas*			3	6,000	0.050	1,950	9,750
			T. derasa			2		0.033		6,470
			H. hippopus			4		0.066		13,000
P-2	Transect under power from lat. 2°59′05″N, long. 131°48′30″E. Course 311° T.	Transect ran 1,100 m across sand and scattered coral heads, 1-1.5 m depth. Only large *T. gigas* and *T. derasa*.	*T. gigas*			6	5,500	0.109	600	6,545
			T. derasa			7		0.127		7,636
H-1	Coral head at lat. 2°53′13″N, long. 131°45′14″E.	Lovely live coral, many clams, small and medium, 1-4 m depth.	*T. gigas*			13	900	1.44	175	25,270
			T. derasa			17		1.89		33,075
			H. hippopus			2		0.22		3,888
H-2	Coral head at lat. 2°50′24″N, long. 131°45′30″E.	Fine flat head, small and medium clams, live coral 2-3 m depth.	*T. gigas*			23	1,600	1.44	175	25,270
			T. derasa			19		1.19		20,781
			H. hippopus			6		0.38		6,562
				TOTAL	*T. gigas*	82	43,800 m^2		6,835 ha	
					T. derasa	101				
					H. hippopus	58				

Table 2.—Abundance of clams at Helen Reef and the Palau Islands. Numbers adjusted to 2,000 m².

Species	Circle No. 1	Circle No. 2	Transect No. 1	Transect No. 2	Hardy & Hardy
T. crocea	138	200	Not counted		275
T. maxima	63	62	Not counted		11
H. hippopus	13	4	3	3	8
T. squamosa	0	0	0	1	13
T. derasa	2	3	3	15	11
T. gigas	6	4	1	10	4

general bottom type and the water depth. Only the three largest species, *T. gigas*, *T. derasa*, and *H. hippopus*, were recorded, and *T. gigas* and some *T. derasa* were measured. (2) Areal: Two circles, each with a radius of 25 m (2,000 m²), were laid out around reference stakes. All of the clams occurring within this circle were counted and measured. (3) Drift transects: A small boat was allowed to drift across the reef with the current while swimmers holding on to the side counted *H. hippopus* and *T. derasa* and counted and measured *T. gigas* and some *T. derasa*. (4) Towing: The boat under power towed swimmers slowly across the reef, and they counted the three largest species. (5) Power tows: Swimmers were towed along the reef between transects to estimate the densities of clams. Power towing provided an indication of the variability of the occurrence of clams in areas of the reef between transects.

The centers of the two circular surveys and the starting points of the two line transects were marked with bronze pipes imbedded in quick-hardening cement. The locations of these marks to the nearest second of arc are given in Table 1, together with the starting points and directions of the drift and tow transects. All positions are taken from the Navy Hydrographic Office chart of Helen Reef, No. 6072, 1st edition, April 1944. Areas not actually measured by transect were taken from the chart with a planimeter. All clam measurements are straight-line valve length made with meter stick calipers, a method that was unsatisfactory for the larger specimens owing to the shortness of the caliper jaws and the width (curvature) of the valves. The estimated error of measurement was ± 5 mm for clams up to 400-mm shell length. For clams larger than this, the error was probably on the order of ± 25 mm.

RESULTS

The abundance of clams at Helen Reef for the two transects and the two circle surveys is presented in Table 2 with abundance data from the Palau Islands (Hardy and Hardy, 1969) for comparison. For this table both our data and Hardy and Hardy's data have been adjusted to number of clams per 2,000 m² (the area of each circle survey).

Average shell size and log abundance adjusted to 4,000 m² (equivalent to the two circle surveys combined) for the six species are given in Figure 2. Average sizes for Hardy and Hardy's clams were estimated from their Figure 4 and are subject to interpretive error.

Length-frequency data for all *T. gigas* and *T. derasa* measured and for *T. crocea*, *T. maxima*, and *H. hippopus* from the two circle surveys combined are presented in Figure 3.

Measured by planimeter, the area of Helen Reef judged suitable habitat for clams is approximately 5,340 ha. Standing stock estimates for the three larger species were made in several ways. From the data in Table 1 the total numbers counted and the total area surveyed were converted to density per hectare which, when multiplied by total reef area, gave estimates of standing stock. Second, densities calculated for each transect were extrapolated to standing stock for adjacent sections of the reef to adjust for habitat variability. Because the data were available from both linear and areal surveys in two sections, estimates were made using each set independently. Third, estimates based on the two coral heads surveyed resulted in surprisingly high

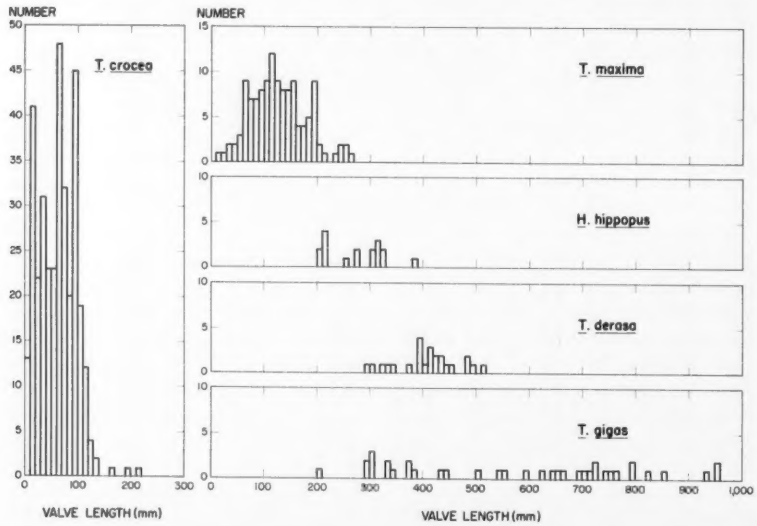


Figure 3.—Length frequency of Tridacnidae at Helen Reef.

standing stock estimates, so total standing stock was calculated with and without the coral head data. Fourth, for the two smaller species, *T. maxima* and *T. crocea*, estimates were made by extrapolating the areal survey data to total reef area resulting in a probable overestimate of abundance. From these estimates maximum and minimum standing stock are obtained (Table 3).

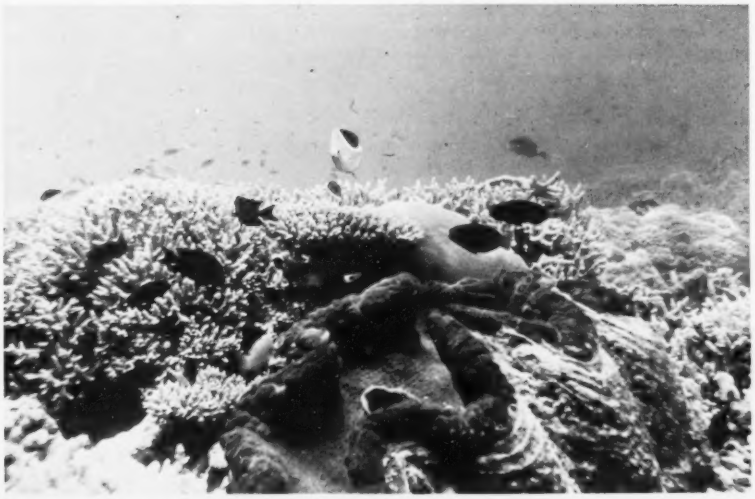
DISCUSSION

Tridacna squamosa was exceedingly rare at Helen Reef, only one specimen being found, whereas *T. maxima* was abundant. This differed from the pattern in the Palaus (Hardy and Hardy, 1969).

The smallest *T. gigas* found was a 200-mm specimen and only two specimens of *T. gigas* shorter than 300 mm were observed. We thought it might be possible to make some recruitment and growth rate estimates by looking for modal size groups with *T. gigas*. However, our measurements are too few to permit any inferences to be drawn.

The growth rates of giant clams are subject to debate in the literature, estimates ranging from a few millimeters per year to an excess of 50 mm per year (see Rosewater, 1965). Observations from Eniwetok based on radioautographs (Bonham, 1965) together with our observations that encrusting coral on the shells seldom is very large, suggest that the growth rates are relatively rapid and that large *T. gigas* probably are 10-20 years of age. Hardy and Hardy's data suggest that the Palaus' *T. gigas* and *T. derasa* are smaller on the average than our Helen Reef clams. For *T. gigas* this may be the result of our extrapolation and interpretation of their data, but in the case of *T. derasa* a size difference appears likely.

With regard to distribution our observations were very similar to Hardy and Hardy's and the rest of the literature. *Tridacna crocea* usually was imbedded in coral heads (*Porites* sp.). *Hippopus hippopus* was found on sandy areas and on occasion on the reef flat, and *T. maxima* was attached to suitable substrate out into the surf zone. *Tridacna derasa* and *T. gigas* occurred in various habitats. To the north of Helen Island, there is an extensive sand flat with occasional small coral patches. Here we found large *T. derasa* and *T. gigas*. Large



The giant clam, shown top and lower left in its natural habitat, is hoisted aboard ship, lower right.

Table 3. — Standing stock estimate.

Species	Based on number per ha: Density no ha	Based on number per ha: Standing stock		Based on number per survey sector: T−1 + T−2	Based on number per survey sector: C−1 + C−2
T. gigas	18.72	99.97 × 10^3		49.77 × 10^3	58.81 × 10^3
T. derasa	26.94	143.86 × 10^3		77.65 × 10^3	32.75 × 10^3
H. hippopus	13.47	71.90 × 10^3		44.61 × 10^3	87.92 × 10^3
T. maxima	3.10 × 10^2	1.66 × 10^6			
T. crocea[1]	10.00 × 10^2	5.34 × 10^6			
				Plus H-1	Plus H-1
T. maxima	3.15 × 10^2	1.68 × 10^6	*T. gigas*	75.04 × 10^3	83.08 × 10^3
T. crocea[2]	6.90 × 10^2	3.68 × 10^6	*T. derasa*	110.73 × 10^3	65.83 × 10^3
			H. hippopus	48.49 × 10^3	91.80 × 10^3
	High estimate	Low estimate			
T. gigas	99.97 × 10^3	49.77 × 10^3			
T. derasa	143.86 × 10^3	32.75 × 10^3			
H. hippopus	94.48 × 10^3	44.61 × 10^3			
				Plus H-2	Plus H-2
T. maxima	1.68 × 10^6	1.66 × 10^6	*T. gigas*	75.04 × 10^3	83.06 × 10^3
T. crocea	5.34 × 10^6	3.68 × 10^6	*T. derasa*	97.93 × 10^3	58.53 × 10^3
			H. hippopus	51.17 × 10^3	94.48 × 10^3

[1]Estimates for *T. maxima* and *T. crocea* from survey C-1.
[2]Estimates for *T. maxima* and *T. crocea* from survey C-2.

T. gigas also occurred along the lagoon edge of the reef south of the pass. Small, medium, and large *T. gigas* and *T. derasa* were found on the coral heads in the lagoon and associated with *Acropora* sp. rubble along the east side of the lagoon. The east and south flats of the reef were hard and relatively bare compared with the west and north sections of the reef except for some sandy portions where *T. gigas* and *T. derasa* were found.

CONCLUSIONS

The clam populations at Helen Reef appeared to be large at the time of the survey. The lack of small *T. gigas* and *T. derasa* suggests that recruitment may be erratic or slow or both. Our lowest standing stock estimates of these two species, the most desirable for shell, are 49.8 × 10^3 *T. gigas* and 32.8 × 10^3 *T. derasa*, suggesting that a moderate fishery for these two species could be prosecuted. Uncertainties with regard to growth rates and recruitment advise caution.

SUMMARY

A standing stock estimate of giant clams, Tridacnidae, at Helen Reef, a small coral atoll in the western Pacific (lat.3°N, long.131°E), was made in March 1972. Eight transects of the reef were made together with two areal surveys 2,000 m^2 each. From these transects, high and low estimates of standing stock for five species of clams, *T. gigas*, *T. derasa*, *T. maxima*, *T. crocea*, and *H. hippopus* were made. Low estimates for the stocks were: *T. gigas* 49.8 × 10^3, *T. derasa* 32.8 × 10^3, *T. maxima* 1.7 × 10^6, *T. crocea* 3.7 × 10^6, and *H. hippopus* 44.6 × 10^3. Only one specimen of the sixth clam, *T. squamosa*, was encountered.

LITERATURE CITED

Bonham, K. 1965. Growth rate of giant clam *Tridacna gigas* at Bikini Atoll as revealed by radioautography. Science (Wash., D.C.) 149:300-302.

Hardy, J. T., and S. A. Hardy. 1969. Ecology of *Tridacna* in Palau. Pac. Sci. 23:467-472.

Rosewater, J. 1965. The family Tridacnidae in the Indo-Pacific. Indo-Pac. Mollusca (Smithson.) 1:347-408.

MFR Paper 1071. From Marine Fisheries Review, *Vol. 36, No. 7, July 1974. Copies of this paper, in limited numbers, are available from D83, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235.*

MFR PAPER 1072

Shrimp maturity can be determined by color of ovaries.

Color Changes in the Ovaries of Penaeid Shrimp as a Determinant of Their Maturity

AUSBON BROWN, JR. and DANIEL PATLAN

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ABSTRACT

The maturation sequence of penaeid shrimp is presented as pictorial illustrations. The major color changes occurring in the ovary are shown. The stages presented include the undeveloped, developing, and the early ripe to ripe stages.

INTRODUCTION

It has been observed that ovaries of penaeid shrimp progress through a series of color changes from immaturity to maturity (King, 1948; Cummings, 1961). These color changes have enabled biologists to determine when penaeid shrimp were sufficiently mature for spawning, for the ripe ovary is easily recognized. The eggs are carried internally, but the ovarian lobes are visible dorsally along the abdomen or tail. Ripe ovaries of the pink shrimp (*Penaeus duorarum*) and brown shrimp (*Penaeus aztecus*) appear olive green and those of the white shrimp (*Penaeus setiferus*) olive brown (Cook and Murphy, 1969). Ripe and early ripe shrimp cannot be separated by gross observations, but the increased "greenness" of the ovaries does indicate that the shrimp has reached the early ripe condition (Cummings, 1961).

The reproductive system of female penaeid shrimp consists of paired ovaries, oviducts, and a single thelycum. The ovaries are partly fused, bilaterally symmetrical bodies extending in the mature animal for nearly its entire length, usually from the cardiac region of the stomach to the telson. In the cephalothoracic region each organ bears a slender anterior lobe and in most cases seven or eight finger-like projections. A pair of lobes, one from each ovary, extend the length of the abdomen (King, 1948; Eldred, 1958).

The ability to determine when shrimp are mature is very important when the expense of gathering shrimp for brood stock is considered. This paper is intended to eliminate some of the errors in selecting gravid shrimp for rearing experiments in aquaculture.

MATERIALS AND METHODS

All shrimp examined in this study were collected offshore on board a commercial trawler. After collection, the live shrimp were kept in ice chests with constant aeration provided by portable aerators. Approximately 8 to 10 shrimp exhibiting various stages of ovarian development were placed in each ice chest. These animals were further culled prior to photographing.

The shrimp were photographed as soon as possible, with attention focused primarily on those animals ready for spawning. However, for contrast, other developmental stages were included. The stages of primary importance in the opinion of the authors consist of the undeveloped, developing, and the early ripe to ripe stages.

The shrimp were photographed with a Polaroid MP-3[1] camera and a 2¼ × 2¼ inch role film holder. Two light banks of three number one photofloods placed at a 45° angle were used. Kodak Ektachrome-X, daylight-type film, was used. The lens was a Rodenstock-Ysaron 5-inch (127-mm) with an 80B conversion filter (A.S.A. rating of 20). Exposures were 1/60 of a second at *f*/8.

STAGES OF OVARIAN DEVELOPMENT

The three developmental stages considered in this paper are the undeveloped (transparent, small ovaries); the developing (larger, yellowish, with increasing pigmentation); and early ripe to ripe stages (intense green color with a further increase in size).

Undeveloped Ovaries

Cummings (1961) and King (1948), working with the pink shrimp and white shrimp, respectively, characterized the ovaries in this stage as small, translucent, flaccid, difficult to remove, and invisible through the exoskeleton (Figs. 1 and 2). It can be

[1]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

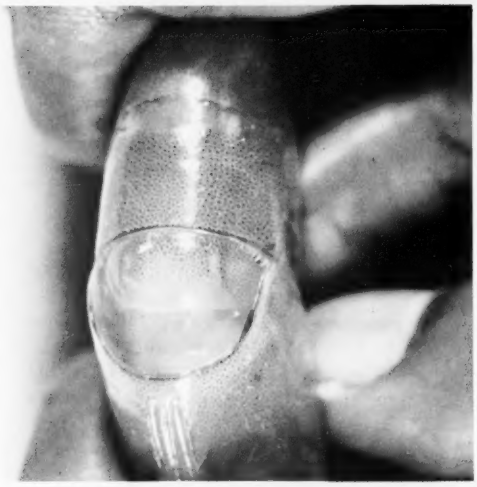
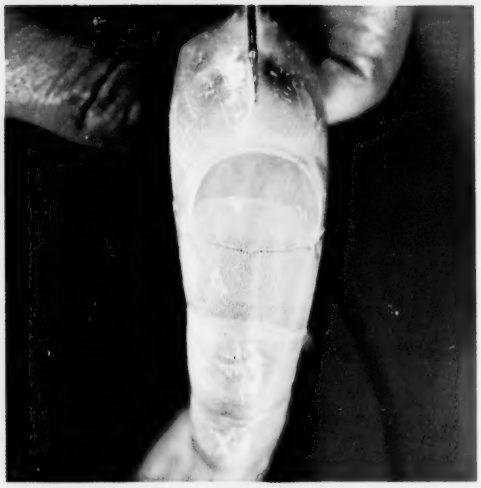


Figure 1.—*Penaeus aztecus*, left, with undeveloped ovaries.

Figure 2.—*Penaeus setiferus*, right, with undeveloped ovaries.



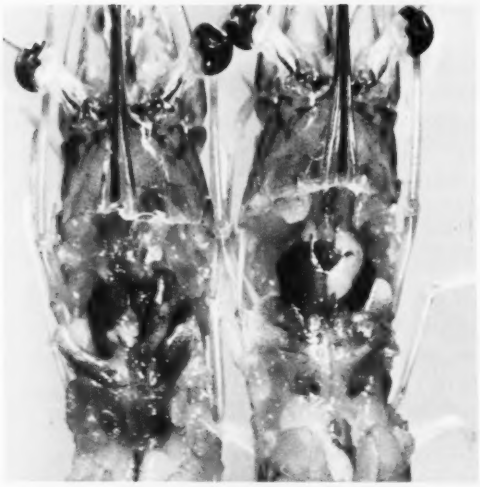


Figure 5.—*Penaeus setiferus*, left, with ovaries exposed showing increased melaophores associated with the yellow developing phase of the ovaries.

Figure 6.—*Penaeus aztecus*, right, showing increase in size of ovaries and apparent red melanophores.

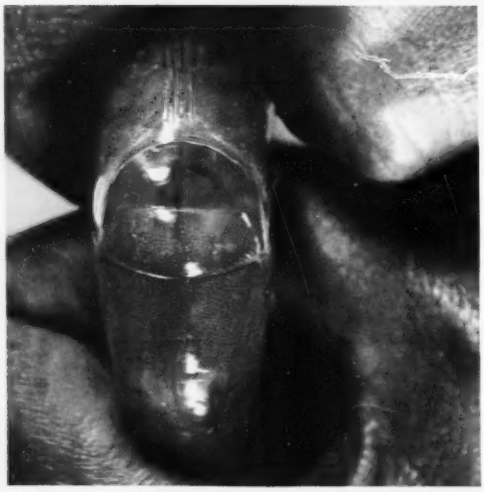


Figure 9.—"Greenness" of the ovaries of *P. aztecus*, left, during ripe or early ripe stages.

Figure 10.—Darker green color mature *P. aztecus*, right.

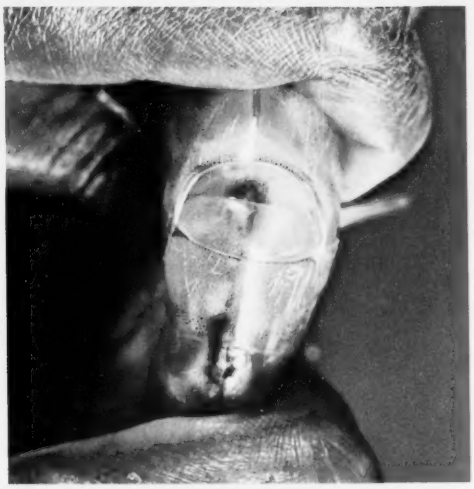
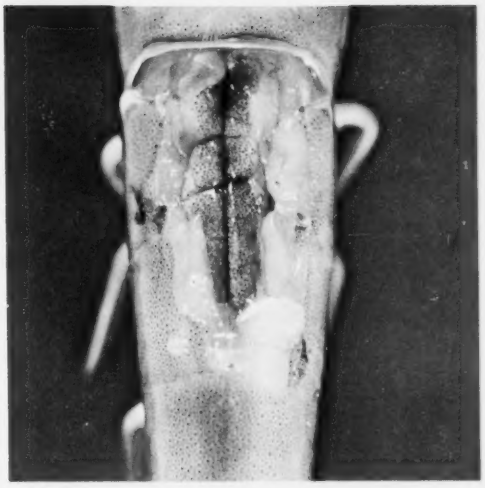


Figure 3.—*Penaeus setiferus*, left, with developing ovaries.
Figure 4.—*Penaeus setiferus*, right, with developing ovaries exposed.



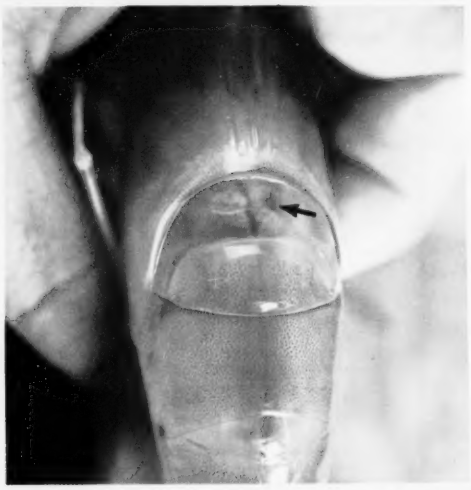


Figure 7.—*Penaeus aztecus*, left, with concentration of red melanophores immediately underneath the posterior end of the carapace.

Figure 8.—"Greenness" of the ovaries of *P. aztecus*, right, during ripe or early ripe stages.

Figure 11.—A, B, C. Abdominal and anterior segments of the ovary of *P. aztecus*, left.

Figure 12.—A, B, C. Three of the most important stages in the maturation of *P. aztecus*, right.

A B C

A B C

seen from observing the photographs that there is little difference between the brown shrimp and the white shrimp except possibly the natural coloration of the animals, the lighter colored of the two being the white shrimp.

Developing or Yellow Ovaries

This stage in ovarian development in the white shrimp has been characterized by an increase in the size of the ovaries and a darkening color dorsally due to scattered melanophores (Figs. 3, 4, and 5).

The darker coloration of the ovaries in the white shrimp might cause them to be mistaken for the ripe or early ripe ovaries. Upon closer examination on the ventral surface of the ovary, however, a yellow color will be detected that is indicative of the developing stage of the ovaries.

In the brown shrimp this stage is generally the same as in the white shrimp with a possible difference being in the color of melanophores. The melanophores in the brown shrimp appear pink to red in color (Figs. 6 and 7) instead of the dark green color of the melanophores in the white shrimp. The pinkish red color of the ovaries of the brown shrimp during this stage makes it virtually impossible to confuse it with the "green color" of the early ripe or ripe shrimp.

Ripe or Nearly Ripe Ovaries

Unfortunately, during the time that shrimp were being collected for this paper, we were unable to catch any white shrimp that properly illustrate the ripe stage of ovarian development.

Cummings (1961), working with the pink shrimp, characterized the ripe or nearly ripe ovaries as having a glaucous color which is darker in more mature ovaries. This is essentially true for the brown shrimp, in which the ovaries are green to dark green in fresh specimens (Figs. 8 and 9). In the more advanced stages of maturity, the ovaries in the brown shrimp take on an even darker green color (Fig. 10). This particular coloration (see also Fig. 11) is the color or stage of choice for spawning. The ovaries have increased in size and the anterior lateral projections are quite evident. These projections are dissected out in the brown shrimp (Figs. 11B and 11C) to illustrate the profuse nature of the projections. The abdominal lobes have also been exposed (Fig. 11A) to illustrate their bilateral nature.

For a comparison of the three more important stages, a photograph was taken (Fig. 12) in which the undeveloped (A), developing (B), and early ripe to ripe (C) are included. The size and transparency of the undeveloped ovaries are noteworthy. The developing stage again shows the increased growth of the ovary but the yellowish color remains, characteristic of the developing stage. The ovaries of the early ripe to ripe stages are more turgid, darker green in color, and larger in size than those in both the undeveloped and developing stages.

DISCUSSION

During transit from offshore to the laboratory, noticeable color changes have been noted in the integument of the shrimp. These superficial color changes may be caused in part by the increase in illumination from the time of capture (night) to the time of their arrival at the laboratory (daylight) (Fingerman, 1970). Apparently, the integumental color changes do not affect the spawning activity of the shrimp.

In the process of gathering mature white shrimp for spawning and rearing experiments, a certain degree of caution must be exercised in the determination of maturity. The developing stage of the white shrimp superficially resembles the mature stage. In contrast, however, there is little chance that a developing stage of the brown shrimp can be mistaken for the mature because of the pinkish red color associated with the developing stage and the green color of the mature stage.

LITERATURE CITED

Cook, H. L., and M. A. Murphy. 1969. The culture of larval penaeid shrimp. Trans. Am. Fish. Soc. 98:751-754.

Cummings, W. C. 1961. Maturation and spawning of the pink shrimp, *Penaeus duorarum* Burkenroad. Trans. Am. Fish. Soc. 90:462-468.

Eldred, B. 1958. Observations on the structural development of the genitalia and the impregnation of the pink shrimp, *Penaeus duorarum* Burkenroad. Fla. State Board Conserv. Mar. Lab., Tech. Ser. 23, 26 p.

Fingerman, M. 1970. Perspectives in crustacean endocrinology. Scientia CV: N DCIC-DCC.

King, J. E. 1948. A study of the reproductive organs of the common marine shrimp, *Penaeus setiferus* (Linnaeus). Biol. Bull. (Woods Hole) 94:244-262.

MFR Paper 1072. From Marine Fisheries Review, *Vol. 36, No. 7, July 1974. Copies of this paper, in limited numbers, are available from D83, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235.*

MFR PAPER 1073

Rotation of harvest techniques might boost bay scallop production.

The Bay Scallop Makes Its Bed of Seagrass

GORDON W. THAYER and
HARVEY H. STUART

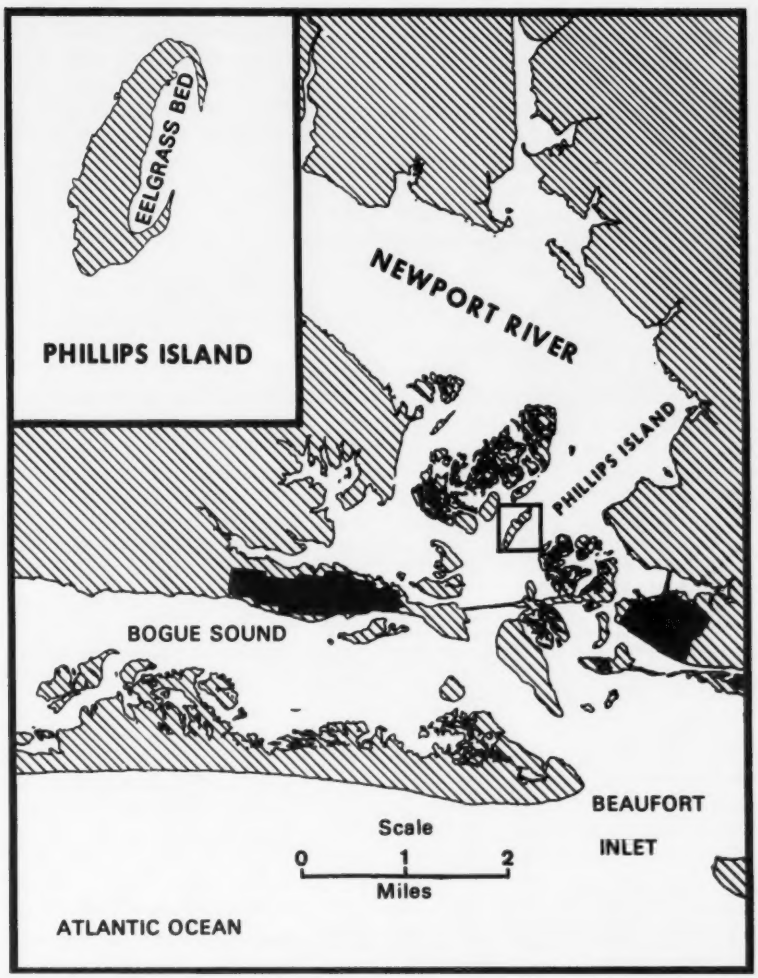


Figure 1.—Diagram of the Beaufort-Morehead City, N.C. area showing the location of the Newport River estuary and Phillips Island.

ABSTRACT

The bay scallop, Argopecten irradians, *an important commercial organism in eight Atlantic coast states, is most often found associated with seagrass. In North Carolina there have been numerous occasions when one or more years of good scallop harvest have been followed by several years of poor harvest, the most recent being 1970-1972. Commercial dredging and trawling for scallops and fish in shallow estuaries disrupt the vegetation and bottom, and this may impede the regrowth of the grass to which larval bay scallops attach. Preliminary data are presented which show that commercial dredging does significantly decrease both scallop and grass density, and it is suggested that annual or biennial rotation of scallop harvesting techniques might increase scallop productivity.*

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The bay scallop, *Argopecten irradians*, has a wide distribution along the Atlantic and Gulf coasts of North America (Sastry, 1963, 1970) where it inhabits bays, sounds, and estuaries (Gutsell, 1930). In these areas it is most often found associated with eelgrass, *Zostera marina*, or other seagrasses. The bay scallop is important commercially in Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Virginia, North Carolina, and Florida.

In the 42 years for which data on commercial landings of bay scallops in North Carolina are available (statistical surveys were not made in all years), the commercial harvest has fluctuated considerably both in pounds of meat landed and the dollar value of the landings (Table 1). During 1968-1969 the harvest averaged $392,000 but this dropped to $81,000 during 1970-1972. In North Carolina only Carteret and Onslow counties account for the total commercial landings.

Table 1.—Production and value of commercial bay scallop catches in North Carolina (Carteret and Onslow Counties). Table taken from p. 444 of the North Carolina Commercial Fishery Statistics Landings 1880-1970, Vol. 2. Data for 1971 and 1972 were provided by Statistics and Market News Division, NMFS, Beaufort, NC 28516.

Date	Thousand Pounds	Thousand Dollars	Date	Thousand Pounds	Thousand Dollars
1880	16	1	1952	254	126
1890	18	1	1953	65	33
1897	118	6	1954	72	26
1902	13	1	1955	78	39
1918	423	32	1956	125	63
1923	554	46	1957	109	37
1927	835	120	1958	169	58
1928	1,394	126	1959	128	51
1929	686	38	1960	69	27
1930	432	54	1961	106	42
1931	495	50	1962	168	67
1932	91	6	1963	321	122
1934	36	5	1964	340	173
1936	99	14	1965	379	196
1937	62	12	1966	399	184
1938	30	8	1967	387	211
1939	33	6	1968	639	402
1940	34	4	1969	613	383
1945	22	8	1970	130	91
1950	72	38	1971	60	42
1951	183	96	1972	128	110

Gutsell (1930) suggested that the association between bay scallops and seagrasses arises in part because the grass provides an above-sediment surface for the attachment of the scallop post-veliger larval stage. Later, the organisms detach, grow to adult size, reproduce within one or two years and then are harvested or die. This association also was recognized in the 1930's when pronounced decreases in abundance of bay scallops were observed following the disappearance of eelgrass along the Atlantic coast of North America (Stauffer, 1937; Dreyer and Castle, 1941; Marshall, 1947). The larvae are not solely dependent upon submerged vegetation since they will settle upon sessile animals and shells. Kirby-Smith (1970), however, noted that only those larvae settling on relatively stable eelgrass beds appear to form reproductively significant populations in North Carolina, whereas Marshall (1947) found that the Niantic River estuary in Connecticut has suitable substrate for their attachment in the absence of eelgrass and other submerged grasses.

The activities of commercial fishermen using bottom trawls in the bays, sounds, and estuaries frequently conflict with the success of eelgrass and thus, bay scallops. In North Carolina where bay scallops generally occur in conjunction with eelgrass, scallops are harvested by bar dredges (50 pounds maximum dredge weight) and hand rakes. Both methods tend to uproot the grass, but the former does so over a large area. Intense commercial dredging and trawling for scallops and fishes disrupt the vegetation and bottom and may impede the reestablishment of the eelgrass for the attachment of the post-veliger larval stage of the bay scallop. This activity stirs the substrate and promotes oxidation of the sediments so that recolonization by eelgrass and by scallops may be reduced (Wolfe, Thayer, and Williams, 1972).

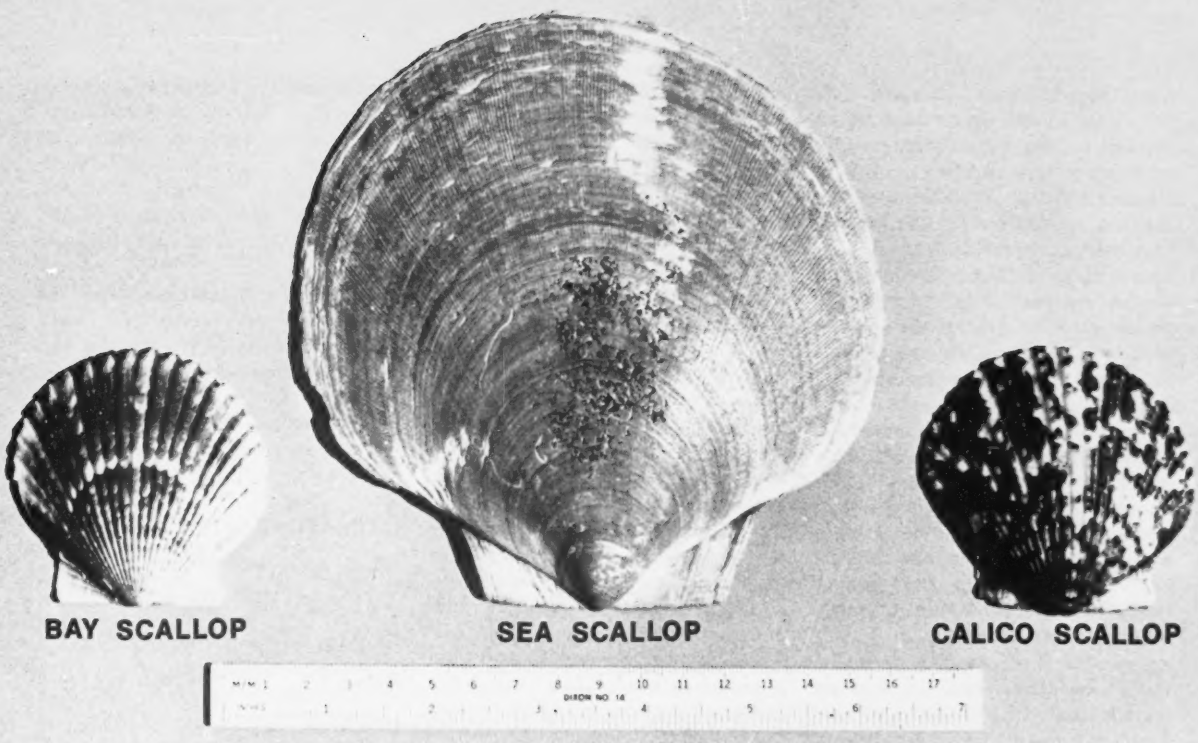
Since 1889, there have been numerous occasions when one or more years of good bay scallop harvest in North Carolina have been followed by several years of poor harvest, the most recent being 1970-1972 (Table 1).

Table 2.—Number of bay scallops/m² and dry weight of eelgrass (grams/m²) collected from an area of an eelgrass bed in the Newport River estuary where there had been commercial raking for bay scallops between December 3 and 17, 1973. Results for three samples on each date are shown.

	Date									
	Jun 25	Jul 11	Jul 25	Aug 8	Aug 22	Sep 27	Oct 31	Nov 20	Dec 19	Jan 16
Number of scallops	48	32	24	36	44	12	0	12	16	12
	36	12	32	28	24	48	28	16	16	16
	28	8	16	32	28	12	16	24	20	20
Average for June-November = 24.8/m²										
Average for December-January = 16.7/m²										
Dry weight of grass	302.0	247.2	195.2	168.0	248.4	84.0	6.4	71.6	62.4	78.2
	240.0	275.2	293.6	224.0	258.4	154.0	56.8	169.2	229.6	196.4
	260.4	287.2	293.6	264.4	280.0	109.6	58.8	177.6	120.0	156.6
Average for June-November = 196.9 g/m²										
Average for December-January = 140.5 g/m²										

Table 3.—Number of bay scallops/m² and dry weight of eelgrass (grams/m²) collected from an area of an eelgrass bed in the Newport River estuary where there had been both hand raking and dredging for scallops between December 3 and 17, 1973. Results for two samples on each date are shown.

	Date									
	Jun 25	Jul 11	Jul 25	Aug 8	Aug 22	Sep 27	Oct 31	Nov 20	Dec 19	Jan 16
Number of scallops	16	24	16	44	32	20	0	24	8	4
	4	20	12	20	36	8	24	16	0	0
Average for June-November = 19.5/m²										
Average for December-January = 3.0/m²										
Dry weight of grass	213.2	182.4	259.6	254.0	278.8	80.8	39.6	143.2	58.8	53.2
	188.4	229.6	193.6	225.2	195.6	54.4	61.2	153.2	125.2	80.8
Average for June-November = 172.0 g/m²										
Average for December-January = 79.5 g/m²										



Relative sizes of the bay, sea and calico scallops are indicated above. Though gourmets prize the bay scallop, the larger sea scallop is more often served. The calico scallop is regarded as "underutilized."

Usually, the poor harvests have been associated with poor crops of eelgrass, which in some instances may have resulted in part from low salinities after hurricanes in the area (1954-1956; 1960-1961). However, since the major hurricane season is during summer and fall, and the scallop season traditionally does not begin until December, hurricanes should influence the succeeding year's eelgrass crop and scallop harvest. Therefore, some other factor or factors must have been responsible for the poor scallop harvests during 1953 and 1960, as well as the poor harvests of 1970-1972 when North Carolina experienced only minor hurricane disturbance.

Since 1969, personnel at the Atlantic Estuarine Fisheries Center, NMFS, Beaufort, N.C., have been studying an eelgrass bed in the Newport River estuary (Fig. 1) to identify the species of the community and to measure their abundance and biomass. We also are determining the movement of energy and materials through the community (Thayer, Adams, and LaCroix, In press). Although bay scallops were present in this area throughout the study, they were not an important part of the community before 1973. Possible reasons for this are that: (1) the eelgrass bed is relatively new (it has only been a permanent feature since 1968); (2) the bed is the only one in the Newport River estuary; and (3) grass and scallop beds nearest to the Newport River are approximately a mile away. In addition, Adams (1974) has shown that young scallops are food for pinfish, boxfish, and toadfish, all of which are present in grass beds. Quantitative collections of organisms and eelgrass made during summer of 1973 indicated that bay scallops were a very important part of the community. Scalloping season opened in North Carolina on December 3, 1973, and during December 3, 5, 10, and 17, a number of commercial fishermen harvested scallops from the area. This enabled us to estimate the effect of commercial harvesting techniques on both scallop and eelgrass abundance.

Dredgers worked the eelgrass bed on only one morning and this was limited to one area of the bed, whereas raking occurred throughout the bed during the four days of scalloping. We estimated the dredging occurred for 2 man-hours and raking for 6 man-hours. Our data suggest that the small amount of time spent dredging one area of the bed had a significant influence on the abundance of both grass and scallops, whereas raking did not.

Table 2 shows the results of our collections in the area of the grass bed subjected only to raking. The number of scallops varied from 0 to 44/m^2 before the opening of the season and averaged 24.8/m^2, whereas after the estimated 6 man-hours of harvest effort, scallop density ranged

from 12 to 20/m² and averaged 16.7/m². Grass density decreased from an average of 196.9 grams dry weight/m² between June and November to a mean of 140.5 g/m² in December and January, a decrease of 56.4 g/m². Statistical analyses (analysis of variance and *t*-tests for collections with unequal sample sizes) indicated no significant difference between scallop or grass density in the raked area before and after the opening of scallop season.

The area that had been subjected to both commercial raking and dredging activities, even though the latter was estimated at only 2 man-hours, showed a statistically significant decrease in both scallop and eelgrass abundance. During the period June through November 1973, scallop density ranged from 0 to 44/m² and averaged 19.5/m², whereas after the opening of the season on December 3, densities ranged from 0-8/m² and averaged 3.0/m² (Table 3). Eelgrass density decreased from an average of 172 grams dry weight/m² between June and November to 79.5 g/m² during December and January. Thus, there had been a decline of 16.5 scallops/m² and 92.5 grams of eelgrass/m² during commercial harvest by both dredging and raking in this area.

The combined activity of commercial harvest by raking and dredging reduced both the scallop population and the substrate (eelgrass) upon which larval scallops are dependent for attachment, to a much greater extent than did raking alone. The information suggests dredging does the greater damage. Although thumbnail sized scallops (1-3 cm shell size) were present throughout the bed prior to the opening of the scallop season, they were not abundant, averaging 3.5/m² for the bed. There was an increase in abundance in mid-December in both areas, but in samples collected during January, thumbnail scallops were found only in the area subjected to raking and not in the area which had been subjected to both raking and dredging.

Low grass abundance and resultant poor scallop harvest (H. Davis and K. Harris, Statistics and Market News Division, NMFS, Beaufort, NC 28516, pers. comm.) may be due to repeated dredging and uprooting of the grass resulting in oxidation of the sediments which impedes regrowth of the grass to which the larval scallops attach. These preliminary data should be followed by supplemental information on rates of recovery and repopulation by grass and scallops in areas dredged. It seems clear, however, that repeated dredging in successive years will inhibit grass and scallop production. This leads to the conclusion that scallop productivity might be increased by an annual or biennial rotation of the type of harvesting technique permitted in a particular area. Portions of estuaries, sounds, and bays could be restricted to harvest by raking for a period of one to two years while the remaining portions would be open to dredging. Following this period the restrictions would be reversed to promote recovery of the area subjected to dredging.

The State of North Carolina has recognized the value of our research efforts on eelgrass communities and by proclamation has established the eelgrass bed in the Newport River estuary as a State-Federal research preserve. We plan cooperative efforts between the Atlantic Estuarine Fisheries Center and the Biology Section of the North Carolina Division of Commercial and Sports Fisheries, Morehead City, N. C., to study the dependency of many commercial and noncommercial, but ecologically important, organisms in seagrass beds in the Beaufort, N. C., area.

ACKNOWLEDGMENT

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LITERATURE CITED

Adams, S. M. 1974. Structural and functional analysis of eelgrass fish communities. Ph.D. Thesis, Univ. N. C., Chapel Hill.

Dreyer, W. A., and W. A. Castle. 1941. Occurrence of the bay scallop, *Pecten irradians*. Ecology 22:425-427.

Gutsell, J. S. 1930. Natural history of the bay scallop. Bull. U.S. Bur. Fish. 46:569-632.

Kirby-Smith, W. W. 1970. Growth of the scallops, *Argopecten irradians concentritus* (Say) and *Argopecten-gibbus* (Linné), as influenced by food and temperature. Ph.D. Thesis, Duke Univ., Durham, N. C., 139 p.

Marshall, N. 1947. Abundance of bay scallops in the absence of eelgrass. Ecology 28:321-322.

North Carolina Commercial Fishery Statistics Landings 1880-1970. 1971. NMFS Division of Statistics and Market News, Beaufort, N. C., 470 p.

Sastry, A. N. 1963. Reproduction of the bay scallop, *Aequipecten irradians* Lamarck. Influence of temperature on maturation and spawning. Biol. Bull. (Woods Hole) 125:146-153.

Sastry, A. N. 1970. Reproductive physiological variation in latitudinally separated populations of the bay scallop, *Aequipecten irradians* Lamarck. Biol. Bull. (Woods Hole) 138:56-65.

Stauffer, R. C. 1937. Changes in the invertebrate community of a lagoon after disappearance of eel grass. Ecology 18: 427-431.

Thayer, G. W., S. M. Adams, and M. W. LaCroix. In press. Structural and functional aspects of a recently established *Zostera marina* community. Second Int. Estuarine Res. Conf., Myrtle Beach, S. C., 15-18 Oct. 1973.

Wolfe, D. A., G. W. Thayer, and R. B. Williams. 1972. Ecological effects of man's activities on temperate estuarine eelgrass communities. Background paper for the Coastal Zone Workshop, Woods Hole, Mass., 22 May-3 June 1972.

MFR Paper 1073. From Marine Fisheries Review, *Vol. 36, No. 7, July 1974. Copies of this paper, in limited numbers, are available from D83, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235.*

MFR PAPER 1074

Effects of Prudhoe Bay Crude Oil on Molting Tanner Crabs, *Chionoecetes bairdi*

JOHN F. KARINEN and STANLEY D. RICE

ABSTRACT

Premolt and postmolt juvenile male Tanner crabs, Chionoecetes bairdi, *from Alaska waters were exposed to Prudhoe Bay crude oil in static bioassays in the laboratory. Crabs in both stages were similarly susceptible to crude oil; the estimated 48-hour TLm (median tolerance limits) values were 0.56 ml oil/liter. Molting success decreased with increasing exposure of crabs to oil, and newly molted crabs autotomized limbs during exposure to oil. Relating the results of our study to the known behavior of crabs and the documented behavior of oil spills in the ocean suggests that oil spilled in Alaska waters would harm the Tanner crab resources. The impact on all crab resources of chronic low-level oil pollution from the ballast water discharged into Prince William Sound is unknown. This study further illustrates our present state of ignorance concerning the biological effects of oil in the marine environment.*

Alaska has an abundance of both living marine resources and petroleum and faces the problem of their compatible utilization. The proposed transport of Prudhoe Bay oil to Valdez in Prince William Sound via pipeline requires subsequent transfer to tankers for marine shipment, which poses a potential for contact between oil and marine animals. Even if catastrophic spills are avoided, chronic rates of oil pollution discharged at depth from the ballast-water treatment plant at Port Valdez could approximate 13 barrels of oil per day plus incidental surface spillage during loading operations (U.S. Department of Interior, 1972).

Prince William Sound is a major fishing area for several commercial species, e.g. salmon, *Oncorhynchus* spp.; king crabs, *Paralithodes camtschatica;* and Dungeness crabs, *Cancer magister,* and has recently become a major producing area for Tanner crabs, *Chionoecetes bairdi*. More than 12 million pounds of Tanner crabs were taken in Prince William Sound between January and June 1973—a catch second only to the Kodiak area in volume landed. Prince William Sound is also a nursery area for Tanner crabs; juveniles were abundant and widespread in a trawl survey covering the eastern and northern parts of the sound (Van Hyning and Cooney, 1972). In addition to their commercial value, Tanner crabs are representative of the large group of marine crustaceans valuable in themselves as part of the food web, both as larvae and adults.

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The effects of oil on marine life in subarctic marine ecosystems like Prince William Sound are unknown and are difficult to predict because of a lack of appropriate research. That massive quantities of oil would have catastrophic effects on marine life is quite apparent, but the effects of chronic exposure to sublethal concentrations of oil are less certain. A growing body of evidence indicates that chronic exposure to low levels of oil may be more significant to the conservation of the fishery resources than occasional catastrophic spills (Blumer, 1970; Kuhnhold, 1970; Whittle and Blumer, 1970; Rice, 1973). Blumer, Mullin, and Guillard (1970) and Blumer, Sousa, and Sass (1970) showed that hydrocarbons, including unsaturated ones, are remarkably stable in the marine food chain. Therefore, it is clearly important to determine the effects of persistent and nonpersistent hydrocarbon pollutants on marine organisms, especially during sensitive stages in the organism's life history.

Molting, a requisite of growth for an animal with an exoskeleton, is a vulnerable period in the life history of crabs and all other crustaceans. Molting occurs many times during the life cycle of an individual, beginning with the larva and ceasing only when growth of the adult stops. The molting cycle is chemically controlled by hormones, and it is therefore likely that chemical pollutants may affect molting. Wells (1972) noted that when lobster larvae were exposed to crude oil, the resulting deaths generally occurred when the larvae were molting. He also showed that sublethal concentrations of oil delayed molting in the early larval stages (1 to 4) during exposures up to 30 days.

Although the study by Wells (1972) was limited in scope, the results suggested that oil has specific effects on the molting process. Because molting is an integral part of crustacean growth and crustaceans are key links

in the marine ecosystem, any pollutant having a detrimental effect on molting should have a far-reaching effect on the ecosystem. Therefore, in the spring of 1973, we initiated a study to determine if short-term static exposure to Prudhoe Bay crude oil affected molting of Tanner crabs. This species was selected because of the combination of its availability to us and its commercial and ecological significance. Specific questions we investigated were: (1) How toxic is Prudhoe Bay oil to premolt and newly molted Tanner crabs? (2) Does short-term exposure of premolt crabs to oil at sublethal levels cause molt arrest or delayed mortality after molting? (3) Does oil interfere with the hardening of the exoskeleton or have other observable effects?

Figure 1.—Water bath and aerated containers used in static acute bioassays with crabs. Aeration tubes are glass-tipped to prevent contact of oil-water solution with tubing.

METHODS

Male Tanner crabs were collected by scuba divers in March 1973 from a large group of molting crabs near the head of Auke Bay, lower Lynn Canal, southeastern Alaska. The crabs were held in flowing seawater in the laboratory for 1 to 3 days before each oil exposure test. No attempt was made to separate mature from immature crabs, but most of the crabs were 73 to 115 mm in carapace width, a size range in which male Tanner crabs are usually sexually immature (Brown and Powell, 1972). Test and control animals were handled similarly. None of the crabs were fed before or after exposure to oil, because crabs do not usually feed for several days before or after the molt. The tests were basically of two types: (1) acute toxicity bioassays (includes lethal dosages) with premolt and postmolt crabs to determine differences in median tolerance limits (TLm), and (2) subacute bioassays in which premolt crabs were exposed to oil to study effects on molting. In the latter experiment, the premolt crabs were exposed to lower dosages of oil and placed in holding pens for several weeks to study molting success.

Acute Bioassays with Premolt and Postmolt Crabs

In the acute bioassays with premolt crabs[1] (76 to 110 mm in carapace width), each crab was placed in a glass jar of about 20-liter capacity containing 15 liters of aerated seawater. Water temperatures were maintained at 4.0° to 5.0°C by placing the jars in a circulating cold-water bath (Fig. 1). A measured quantity of oil[2] was put into each jar, and the mixture of water and oil was vigorously agitated with a mechanical stirrer for 1 min at 2,250 rpm. The mixing procedure created a fine emulsion almost immediately which settled up to form a slick within 1 to 2 min after the mechanical stirring stopped. It is assumed that this procedure approximates the standardized shaking procedure of LaRoche, Eisler, and Tarzwell (1970). Twelve test crabs were exposed at each of four doses of oil (0.18, 0.32, 0.56, and 1.00 ml/liter), and 12 control crabs were placed in jars containing only seawater. Forty-eight-hour TLm values for acute bioassays were determined graphically according to the method of Doudoroff et al. (1951). One crab was placed in each jar and the weight of each crab was about 180g, resulting in an average mass to water volume ratio of 12 g/liter. This ratio is three times the recommended ratio of 4 g/liter for static tests; however, in a separate test four crabs in one control jar survived for more than a week (48 g/liter), which indicated that the ratio of 12 g/liter was not so great as to substantially influence the results by inducing physiological stress. Test and control solutions were aerated continuously during the bioassay.

Acute bioassays with postmolt crabs (83 to 115 mm carapace width) were performed in the same way as those

[1]Premolt Tanner crabs that have not molted for a year or more are easily recognized and separated from new-shelled postmolt crabs by the color, wear marks, and epifauna on their carapaces. All premolt crabs used in this study had molted during the previous spring molting season.

[2]Prudhoe Bay crude oil for the experiments had been supplied by Atlantic Richfield Company in a sealed 55-gal. barrel. When the barrel arrived at the laboratory, the contents were transferred to 1-quart cans sealed with Teflon-lined lids to prevent loss of volatile components.

with premolt crabs. The oil concentrations were 0.32, 0.56, and 1.00 ml/liter; 12 crabs were exposed to each concentration in the first experiment and 11 crabs in the second. Crabs of comparable size were used as controls in each experiment.

Subacute Bioassays Involving Molting and Autotomy of Limbs

In the tests of possible subacute or delayed effects of oil on molting, premolt crabs (73 to 114 mm in carapace width) were exposed for 48 hours to three sublethal concentrations of crude oil in seawater[3] (0.32, 0.18, and 0.056 ml/liter) by the same procedures described for the acute bioassays. The exposed crabs and a control group were then transferred to holding pens in the natural environment, where molting success was monitored until all of the control crabs had molted—1½ to 4½ weeks (Fig. 2). The numbers of premolt, postmolt, and dead crabs were recorded every 3 to 5 days, and the growth increment of molted crabs was determined. The hardness of the exoskeleton of the molted crabs in the holding pen was subjectively determined. Three major trials were completed: 40 crabs were exposed to 0.32 ml oil/liter, 30 to 0.18 ml, and 33 to 0.056 ml. The control group contained 32 crabs.

Many surviving postmolt crabs lost limbs (apparently autotomized) while exposed to oil during the 48-hour subacute bioassays, but only a few premolt crabs lost limbs. Because the loss of several legs or chelae is probably detrimental to crab survival in nature, we repeated the test with crabs of similar postmolt age (about 1 week after molting) to confirm that they were autotomizing their limbs. The crabs were subjected to exposures of oil (0.32 to 1.00 ml/liter for 24 hours) during which the shed legs were counted in the undisturbed jars in the cooling bath (Fig. 3). The jars were smooth inside and contained nothing that could snag a leg or provide a base for the crab to pull against. Tests to evaluate leg loss were also repeated 4 weeks after the peak molt period for Tanner crabs.

[3]The highest concentration of oil (0.32 ml/liter was lethal to 25 percent of the crabs over three trials.

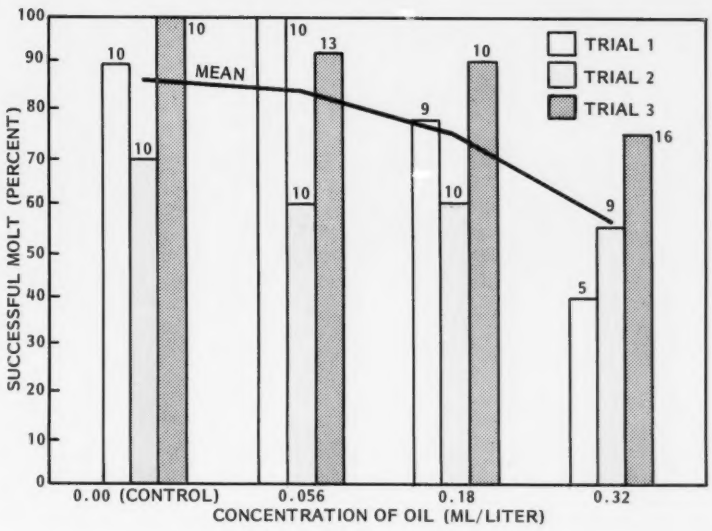

Figure 2.—Molting success of Tanner crabs that survived 48-hour exposure to various concentrations of Prudhoe Bay crude oil. Three successive trials were conducted. The numbers on top of each bar are numbers of crabs surviving the 48-hour exposure and then held to observe their molting success. The curve represents the unweighted mean of the three trials at each concentration.

TOXICITY OF CRUDE OIL TO PREMOLT AND POSTMOLT CRABS

The concentration of oil tolerated by 50 percent of both premolt and postmolt crabs (TLm) for 48 hours at about 5°C was estimated from the bioassays to be 0.56 ml/liter (Table 1). The 24- and 48-hour TLm values of premolt crabs were not apparently different, but the 24-h TLm of postmolt crabs was higher—0.83 ml oil/liter. However, the statistical precision and significance of these TLm values were not examined. Because of the high ratio of tissue mass to water volume (and tissue mass to toxic materials), the TLm estimates may be higher than would have been obtained under ideal conditions (i.e., material is probably more toxic than the tests indicate).

Crabs responded to all concentrations first by increased activity, followed within 60 min at the high oil concentrations by a contraction of the legs; then within 2 to 3 hours complete relaxation and death. Relaxation prior to death may be indicative of narcosis. At the lowest oil concentrations, the crabs remained normally active.

EFFECTS OF CRUDE OIL ON MOLTING SUCCESS

Results of the study in which premolt crabs were exposed to subacute concentrations of crude oil in seawater (Fig. 2) suggest that brief exposure to small amounts of crude oil (0.056

Table 1.—TLm values at 5°C of Prudhoe Bay crude oil for premolt and postmolt juvenile male Tanner crabs. Values are for one bioassay with premolt crabs and the mean of two assays for postmolt crabs.

Hours of exposure	TLm value (ml oil/liter)	
	Premolt crabs	Postmolt crabs
24	0.56	0.83
48	0.56	0.56

Figure 3.—Examples of leg loss in live crabs at various crude oil concentrations. Oil layer has been removed from two highest concentrations.

to 0.32 ml/liter) may have a delayed detrimental effect on molting. Most of the crabs (75 percent) survived the 48-hour exposure to oil at 0.32 ml/liter, and the molting success figures are based on these crabs. The trials were made successively over a period of 2 weeks, and the closer the crabs were to molting, the less sensitive they appeared to be to oil—the percentage that molted and lived after exposure to 0.32 ml/liter increased with each successive experiment (Fig. 2). The experimental crabs were from a group rapidly approaching ecdysis, i.e., trial 1 crabs were further from molting than trial 2 crabs, which were further from molting than trial 3 crabs. It is possible that the progressive physiological changes associated with the molt cycle (Passano, 1960) are accompanied by a change in sensitivity to oil. Although the percentage of crabs that molted and survived a given oil exposure varied considerably among the three trials, survival definitely declined as concentrations of oil increased (Fig. 2). The 32 control crabs (no exposure to oil) had the best overall survival, and all had molted when the experiment was terminated. Failure to molt successfully was usually manifested in incomplete molt and death, but 6 percent of the crabs exposed to oil simply did not molt during the experiment.

The new shell of molted crabs that survived the exposure appeared normal with respect to both morphology and rate of exoskeleton hardening. Growth as indicated by the percent incremental increase in width was the same (27 percent) for exposed and control crabs; however, the effect of limb loss was not considered for either group. That limb loss may reduce body growth as well as stimulate ecdysis was reaffirmed in recent studies by Bennett (1973) and Skinner and Graham (1972), respectively.

Statistical examination of the survival and molting data in Figure 2 by a nonparametric test appropriate for a randomized block design (Friedman, 1937) showed that the proportion of crabs molting in at least one of the treatments, the high-level oil dose, was smaller than the control or lowest oil dose. Therefore, brief exposure of premolt Tanner crabs to crude oil 1 to 4 weeks before molting probably has a detrimental effect on molting. The indication that crabs appeared less sensitive to oil as they approached the molt was not statistically significant.

AUTOTOMY OF LIMBS INDUCED BY EXPOSURE TO OIL

Although we found no difference in survival between postmolt and premolt crabs exposed to oil, the postmolt crabs lost many of their limbs whereas the premolt crabs lost none of theirs. The number of limbs lost by postmolt crabs varied between crabs, but the average increased with increasing oil concentrations both for the 24-hour (11 April) and the 48-hour exposures (29-30 March).

To eliminate mechanical disturbance as a possible factor in the leg loss associated with exposure to oil, the jars containing crabs were not disturbed, moved, or handled in the experiment in which crabs were held for 24 hour until the autotomized legs had been counted. Substantial loss of legs occurred in crabs exposed to 0.56 ml oil/liter (Table 2). At this dose, 64 percent of the crabs were alive after 24 hours of exposure, and these live crabs as a group had lost an average 3.3 legs per crab (range 1 to 8) (Fig. 4). Clearly, the exposure to oil caused the loss—crabs began losing legs within 3 hours. The crabs that died during the 24-hour test had lost an average of 5.5 legs each (range 2 to 7). In several instances, crabs lost all legs on one side, including the cheliped; in other instances both chelipeds plus several other legs were lost. That crabs autotomized several limbs either simultaneously or with little movement was indicated in several instances by detached legs still in place around the bodies of live crabs (Fig. 5). Crabs did not lose regenerated legs as readily as normal legs.

It is not known how long after molting that Tanner crabs continue to be susceptible to dropping legs during exposure to oil. We repeated the tests on 1 May, about 4 weeks after the peak of molting, and seven crabs exposed to 0.56 ml oil/liter for 24 hours dropped only three legs. Apparently, crabs become less vulnerable to oil-induced leg loss with increasing time after molting.

The fact that oil stimulated autotomy in post molt Tanner crabs suggested to us that other crab species and crustaceans may react similarly. However, we exposed premolt and postmolt juvenile king crabs (11.4 g average weight) to sublethal and lethal doses of oil (0.1 to 1.00 ml/liter), and no crabs in either group lost legs.

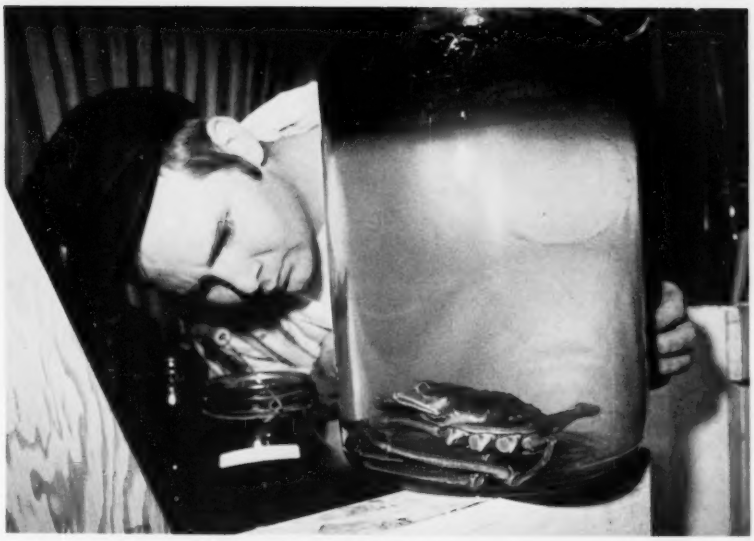

Figure 4.—A common occurrence was the loss of three or more adjacent legs, which seriously hampers the crab's mobility.

DISCUSSION

Molting Tanner crabs were affected in three observable ways by short-term exposure to Prudhoe Bay crude oil under static laboratory conditions. High concentrations killed crabs outright, but lower concentrations had two less obvious effects—reduction in molting success and autotomizing of limbs. Thus even among Tanner crabs that survived an initial exposure to oil, their mortality in the natural environment may be increased, depending on the time of year that exposure occurs and the stage of their molt. Crabs, which constitute about 25 percent of the total number of crustacean species on a worldwide basis, may be particularly susceptible to oil pollution because most occur in shallow waters for part or all of their life cycles. In Alaska, the four major commercial crab species (*Paralithodes camtschatica, P. platypus, Chionoecetes bairdi,* and *Cancer magister*) all enter shallow water in spring and summer to molt, mate, and release their larvae.

The method used in our experiments to mix the oil with the seawater and to introduce the crabs to the oil-seawater mixture makes it impossible to determine whether the water-soluble fractions of the oil are causing the damage or whether exposure of the crab to emulsified oil particles is responsible for the observed effects. Some exposed crabs acquired a very thin film of oil on their exoskeletons, and it is possible that oil passed directly through their gill membranes or body integuments. The 48-hour TLm for juvenile male Tanner crabs was quite high (0.56 ml oil/liter) with respect to total oil; however, the water-soluble fractions, which approximate only 0.1 percent of this value, may be the agents causing damage instead of total oil.

Regardless of what the toxic components are, observations on the behavior of oil from past spills make it reasonable to assume that our experiments approximate the type of oil exposure which crabs could experience under conditions of a spill in estuarine waters.

Campbell and Martin (1973) discuss several instances of formation of extremely stable oil-water emulsions—the oil spilled by the *Torrey Canyon*, the oil spilled in the wreck of the *World Glory* off the coast of South Africa, the oil leaked from offshore wells in Santa Barbara, and the oil spilled from the wreck of the *Arrow* in Chedabucto Bay, Nova Scotia. The emulsions formed over a wide temperature range in these spills contained from 36 to 80 percent water and resulted from several types of oils (Kuwait crude to bunker C fuel).

Table 2. — Autotomy of limbs resulting from exposure of recently molted juvenile male Tanner crabs to different concentrations of crude oil for 48 and 24 hours.

Concentration of oil (ml/liter)	48-hour exposure (29-30 March)					24-hour exposure (11 April)				
	Crabs alive		Average number of limbs lost per crab			Crabs alive		Average number of limbs lost per crab		
	Number	Percent	Alive	Dead	Combined	Number	Percent	Alive	Dead	Combined
0.00	8	100	0.0	0.0	0.0	11	100	0.0	0.0	0.0
0.32	7	58	0.0	0.6	0.25	9	82	0.1	0.0	0.1
0.56	6	50	1.1	3.0	2.0	7	64	3.3	5.5	4.0
1.00	1	8	9.0	4.7	5.0	2	18	3.5	5.1	4.8

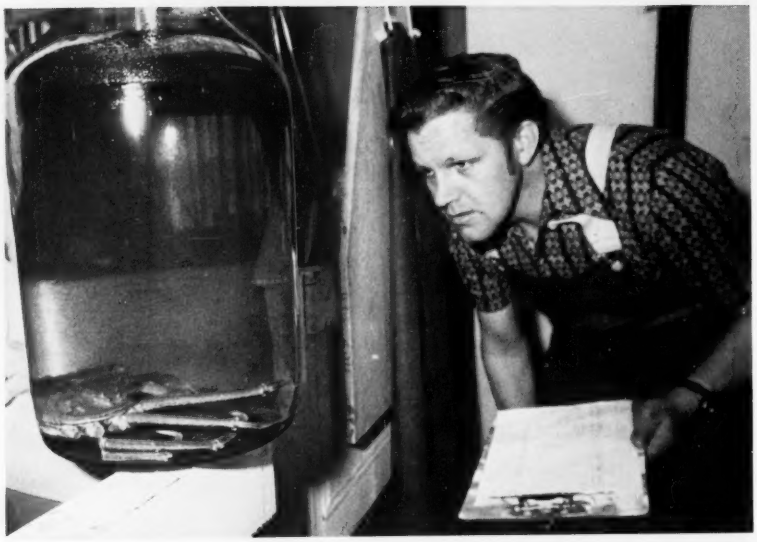

Figure 5.—Crabs autotomized several limbs, either simultaneously or with little movement, as legs remained in place around the body in several instances.

Oil from the *Arrow* (108,000 barrels of bunker C in seawater at temperatures between 0° and 2°C) formed highly stable emulsions and ". . . within 2 weeks of the spill, oil particles were observed down to a depth of 50 m throughout the entire area of the bay (approximately 900 km²). Oil particles were also found outside the bay in a tongue approximately 10 km wide which extended eastward from the mouth of the bay for a distance of 70 km." (Campbell and Martin, 1973.)

Since extremely stable oil-water emulsions were formed over a wide temperature range (spanning temperatures which occur in Alaska waters), we expect that highly stable emulsions will form after oil spills in Alaska and that oil will reach depths occupied by Tanner crabs. There is little doubt that oil spills would have adverse effects on Alaska's Tanner crabs, and that crabs would be especially vulnerable to oil spills in the spring when they move into shallow water to molt and mate; however, it is difficult with available data to predict the magnitude and persistence of these effects.

The effects on marine life of chronic exposure to sublethal concentrations of oil are even more difficult to predict than the effects from large oil spills. It is possible that the large volume-low hydrocarbon concentration effluent (1.3 million barrels per day at 10 ppm oil, according to the U.S. Department of Interior, 1972) from the proposed ballast-water treatment facility in Port Valdez will adversely affect (decreased molting success and increased autotomy) Tanner crabs and other organisms. This effluent will be introduced at depth and will consist of the water-soluble hydrocarbon components from Prudhoe Bay crude oil.

The fact that oil reduces molting success in Tanner crabs and induces newly molted Tanner crabs to autotomize limbs suggests that oil pollution may have adverse effects on crustaceans in general. Because molting is an integral part of crustacean growth and crustaceans are important in the marine environment, any extensive disruption of the molting process of important marine species would be disastrous. Data are needed to measure the effect of oil on molting in other crabs and crustaceans.

Autotomy is a phenomenon generally associated with molting in the crustaceans, where it permits dropping damaged legs that will not slide out of the old exoskeleton. Autotomy of limbs other than at molting is usually associated with mechanical stimulation, although it has been known for some time that autotomy is also stimulated by noxious preserving fluids (Wood and Wood, 1932). The high degree to which autotomy has developed in Tanner crabs, especially during and shortly after the molt, may be detrimental to their survival if they are exposed to chemical pollution. We have observed autotomy within 3 hours of initial exposure to oil, and in nature a sublethal dose could cause crabs to autotomize some limbs. Pollutant-stimulated autotomy could be very significant if it could be induced by the accumulated effects of chronic low-level exposure to oil. The implication is clear: crabs with fewer legs and chelae would be less successful in feeding, defending, migrating, and mating.

The lack of oil-induced autotomy by postmolt Tanner crabs tested 4 weeks after molting, and lack of autotomy in juvenile king crabs in our tests indicates that extrapolation of either of these observations to other species, other life stages, and other crude oil and refined products is not warranted until verified by further specific research.

Our laboratory experiments indicate that oil pollution may cause significant biological damage other than immediate death of the affected organisms. Of immediate need is research to (1) identify and determine the persistence of oil fractions which affect molting and induce leg loss, (2) determine the exposure necessary to affect molting and leg loss, (3) determine the effects of acute exposures of oil on molting and autotomy of other crustaceans, and (4) determine the chronic effects of exposure to oil on molting success and autotomy.

SUMMARY

This study investigated the effects of Prudhoe Bay crude oil on juvenile Tanner crabs during the molting process. High doses of oil caused mortality, while lower doses decreased molting success and induced autotomy of limbs. Because the concentrations of oil used in the experiments were within the concentration range and depth distribution that could occur in real situations in nature, it is quite possible that these and other adverse effects could result from oil spills or from chronic low-level pollution. Specific results of the study are:

1. Median tolerance limits for 48 hours for both premolt and postmolt Tanner crabs was estimated to be 0.56 ml oil/liter.
2. Molting success of premolt crabs after exposure to 0.32 ml oil/liter was significantly lower than molting success of control crabs.
3. Observations of autotomy in recently molted crabs that survived acute oil exposures suggested that delayed and indirect mortality may occur among crabs that survive a short exposure to oil.

ACKNOWLEDGMENTS

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LITERATURE CITED

Bennett, D. B. 1973. The effect of limb loss and regeneration on the growth of the edible crab, *Cancer pagurus*, L. J. Exp. Mar. Biol. Ecol. 13:45-53.

Blumer, M. 1970. Oil contamination and living resources of the sea. FAO (Food Agric. Organ. U.N.) Technical Conference on Marine Pollution and its Effects on Living Resources and Fishing. FIR: MP/70/7C/R-1, 11 p.

Blumer, M., M. M. Mullin, and R. R. L. Guillard. 1970. A polyunsaturated hydrocarbon (3, 6, 9, 12, 15, 18-heneicosahexaene) in the marine food web. Mar. Biol. (Berl.) 6:226-235.

Blumer, M., G. Souza, and J. Sass. 1970. Hydrocarbon pollution of edible shellfish by an oil spill. Mar. Biol. (Berl.) 5:195-202.

Brown, R. B., and G. C. Powell. 1972. Size at maturity in the male Alaskan Tanner crab. *Chionoecetes bairdi*, as determined by chela allometry, reproductive tract weights, and size of precopulatory males. J. Fish. Res. Board Can. 29:423-427.

Campbell, W. J., and S. Martin. 1974. Oil and ice in the Arctic Ocean: possible large-scale interactions. Science (Wash., D.C.) 181:56-58.

Doudoroff, P., B. G. Anderson, G. E. Burdick, P. S. Galtsoff, W. B. Hart, R. Patrick, E. R. Strong, E. W. Surber, and W. M. Van Horn. 1951. Bio-assay methods for the evaluation of acute toxicity of industrial wastes to fish. Sewage Ind. Waste 23:1380-1397.

Friedman, M. 1937. The use of ranks to avoid the assumption of normality implicit in the analysis of variance. J. Am. Stat. Assoc. 32:675-701.

Kuhnhold, W. 1970. The influence of crude oil on fish food. FAO (Food Agric. Organ. U.N.) Technical Conference on Marine Pollution and its Effects on Living Resources and Fishing. FIR: MP/70/E-64.

LaRoche, G., R. Eisler, and C. M. Tarzwell. 1970. Bioassay procedures for oil and oil dispersant toxicity evaluation. J. Water Pollut. Control Fed. 42:1982-1989.

Passano, L. M. 1960. Molting and its control. *In* T. H. Waterman (editor), The physiology of Crustacea. Vol. 1, p. 473-536. Academic Press, N.Y.

Rice, S. 1973. Toxicity and avoidance tests with Prudhoe Bay oil and pink salmon fry. *In* Proceedings of Joint Conference on Prevention and Control of Oil Spills, p. 667-670. American Petroleum Institute, Environmental Protection Agency, and U.S. Coast Guard, Washington, D.C.

Skinner, D. M., and D. E. Graham. 1972. Loss of limbs as a stimulus to ecdysis in Brachyura (true crabs). Biol. Bull. (Woods Hole) 143:222-233.

U.S. Department of the Interior. 1972. Final environmental impact statement proposed trans-Alaska pipeline. Vol. 1. U.S. Gov. Print. Off., Washington, D.C., 322 p.

Van Hyning, J. M., and R. T. Cooney. 1972. The developing fishery for snow crabs in Prince William Sound, Alaska, with observations on biology, size composition, and abundance. Presented at 23d Alaska Science Conference — Science and Policy in the North, Univ. Alaska, 18 p.

Wells, P. G. 1972. Influence of Venezuelan crude oil on lobster larvae. Mar. Pollut. Bull. 3:105-106.

Whittle, K., and M. Blumer. 1970. Interactions between organisms and dissolved organic substance in the sea: Chemical attraction of the starfish *Asterias vulgaris* to oysters. *In* D. Hood (editor), Symposium on organic matter in natural waters, p. 495-507. Univ. Alaska Press, College.

Wood, F. D., and H. E. Wood, II. 1932. Autotomy in decapod crustacea. J. Exp. Zool. 62:1-55.

MFR Paper 1074. from Marine Fisheries Review, *Vol. 36, No. 7, July 1974. Copies of this paper, in limited numbers, are available from D83, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235.*

NOAA/NMFS Developments

Fishermen, Shippers, Flood Forecasters Helped by NOAA Satellite Information

Timely satellite information on ice in the Great Lakes and Alaskan waters, on the location of the Gulf Stream, and on snow cover in several major river basins is now available from the Commerce Department's National Oceanic and Atmospheric Administration.

Up-to-date ice observations help make maritime operations safer and more efficient, while information on the Gulf Stream can aid both commercial shipping and fishermen. Snow cover is an important factor in forecasting floods and estimating water supplies.

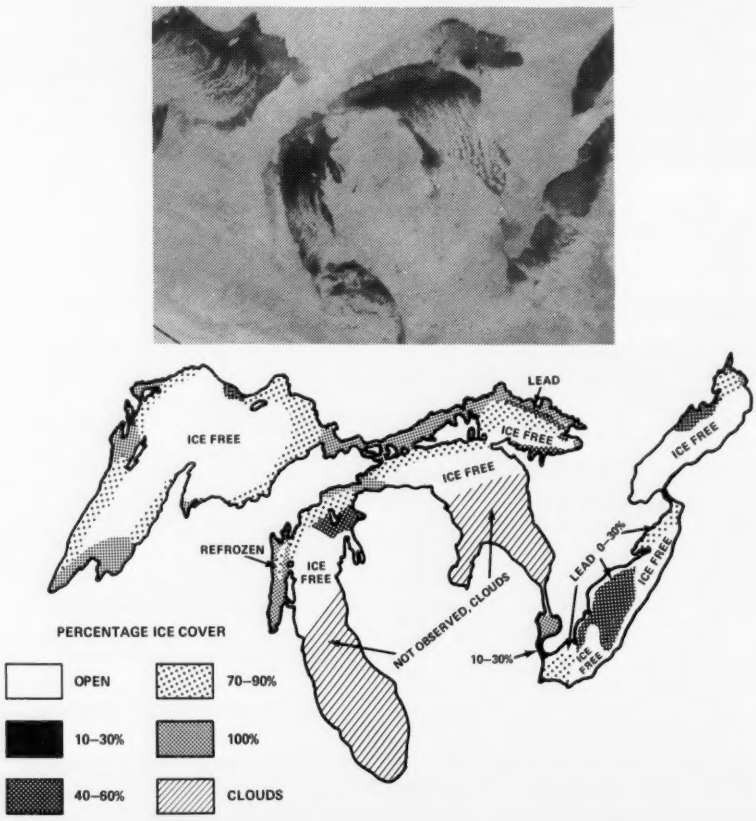
The experimental services, provided by NOAA's National Environmental Satellite Service, are based on detailed, half-mile resolution images obtained by very high resolution radiometer systems aboard polar-orbiting NOAA spacecraft.

To forecast future river flow and flooding, and to estimate potential water supplies, hydrologists in many areas must take into account the amount of water stored in the form of snow. In the western United States, seasonal snow accumulation is measured at thousands of surface locations, and aircraft are used to survey snow cover over large regions. But only the broader view from space can give a complete picture of the extent of snow cover.

Using high-resolution images from NOAA satellites, the extent of snow cover in river basins as small as 2,500 square miles can be mapped to an accuracy of about five percent. A satellite image and a map of the river basin are placed in an optical device called a "zoom transfer scope," which enables the operator to see the satellite image superimposed on the basin map and to register the two. Snow areas appearing in the picture are traced on the map, the areal extent is measured, and the percentage of the basin covered by snow is calculated. The percentage figure is sent through National Weather Service communications systems to the NWS River Forecast Center responsible for predicting river flow, flooding, and potential water supply in the basin. This procedure is carried out each time a relatively cloud-free image of the basin is obtained, and is completed in 36 hours or less after the spacecraft has observed the area.

From the high-resolution images, the Environmental Products Group is currently calculating snow cover percentages for the American River Basin in California, the Willamette River Basin in Oregon, the Genesee River Basin in New York and Pennsylvania, and the Red River of the North in the Dakotas and Minnesota. Seven additional basins are scheduled to be added soon to the operational test program: Arizona's Verde, Salt, and Upper Gila river basins, and four on the upper Columbia River.

Each winter, sea, lake and river ice closes ports and shipping lanes in high latitudes, forcing commercial vessels to remain idle and hampering military ship operations. To plan sea transport in these areas, marine interests need to know where ice exists in ports and along sea routes, and whether the ice is forming or breaking up. The United States, Canada, and other nations operate aircraft reconnaissance programs to gather this



Great Lakes ice cover in early February, as mapped from NOAA-2 very high resolution images.

information. Although the reconnaissance is costly and complex, the economic savings and increased safety afforded to shipping operations have justified this expense. Now earth-orbiting satellites permit more efficient aerial surveillance over vast areas.

Infrared sensing systems on the NOAA satellites allow major ice features to be observed throughout the year over the entire earth. Significant ice boundaries, openings, and thin areas can be detected in the images, and improved estimates of the thickness and physical state of the ice can be deduced from surface temperature information in the infrared images.

Ice charts based on NOAA high-resolution images are prepared and disseminated through National Weather Service facsimile circuits on a regular schedule. Great Lakes ice analyses, issued twice weekly, show open water as well as areas where ice cover ranges from 10 to 30 percent, 40 to 60 percent, 70 to 90 percent, and up to 100 percent. Experimental ice analyses covering the Bering, Chukchi, and Beaufort seas and the Gulf of Alaska are issued weekly. These distinguish between new and multiyear ice and indicate estimated thicknesses of young and first-year ice in ranges of 10 to more than 120 centimeters.

Each week, the Satellite Service prepares and transmits an experimental Gulf Stream analysis chart, showing the surface location and extent of shelf water, slope water, the Gulf Stream itself, and associated cold and warm eddies, as revealed by surface temperature contrasts depicted in the high-resolution infrared images.

Information on the Gulf Stream is of special interest to the shipping and fishing industries. Ships plying east coast routes make use of this large current to speed northbound runs and save fuel. Vessels heading south stay clear of the Gulf Stream, which would slow their progress. The satellite data show the frequent meanders in the Gulf Stream.

Commercial fishermen can use the data on water-mass boundaries from these charts to increase the efficiency of their operations. The nutrients on which fish feed accumulate on the boundaries between shelf and slope water and between slope water and the Gulf Stream, and large concentrations of fish are usually found in such areas.

Ocean Environmental Information Available For Coastal Florida, Georgia, Carolinas

New ocean environmental data are now available for coastal planners of four southeastern states following completion of the first year of a two-year concentrated investigation of coastal waters off Florida, Georgia, and the Carolinas.

The investigation was conducted by four vessels, an aircraft, and several field parties of the Commerce Department's National Oceanic and Atmospheric Administration as part of a new program designed to compress into two years projects previously scheduled for completion in 15 years. Similar concentrated investigations are planned for other east, west and Alaskan coastal areas.

The project began in January 1973 and continued until November 1973. The second and final phase began in April, 1974. Impressive results have been recorded so far in the program which is designed to provide marine information about coastal zones to assist federal, state, local, and private agencies in making decisions concerning environmental problems.

Data processing has been accelerated for the project in order to expedite the release of information. The following data are now available from the 1973 phase of the operation, known as SCOPE (Southern Coastal Plains Expedition).

1. Tidal current data in the following coastal areas: Charleston Harbor, S.C., and southward to and including Ossabaw Sound, Ga. These data are in various stages of processing and will be available in various forms, including magnetic tape, printouts, computer-plots and data analysis forms, from the National Ocean Survey (C33), Rockville, Md. 20852. In due course, the data will be incorporated in the tidal current tables published by the agency.

The data provide information on the speed and direction of the water that flows in and out of the estuaries, information essential to coastal planning, especially in determining the dispersion of pollutants. In connection with the latter, a special study was made aboard a NOAA ship by the Smithsonian Institution to determine the type of suspended sediments, including pollutants, in Port Royal Sound, S.C. This information is available from the National Ocean Survey (C33) or the Smithsonian Institution, attention Dr. J.W. Pierce, Curator, Division of Sedimentology, Museum of Natural History, Washington, D.C. 20560.

2. Shoreline maps which depict the high and low water lines as determined by aerial photography. Copies can be obtained from the National Ocean Survey (C3415). They are important in determining shoreline boundaries, including federal, state, and private. The area covered is from Morehead City, N.C., to St. Augustine, Fla. Not all maps are completely processed yet.

3. Aerial photographs. Coastal planners can use these for studies of the shoreline and for any type of shoreline construction. The boundaries (the high and low water lines) along the coast can be physically seen, although it may be necessary sometimes to enlarge segments of photos to achieve this. The photographs can be obtained from the National Ocean Survey (C3415) for the coastal area extending from Morehead City, N.C., to Cape Canaveral, Fla.

4. Field sheets (also known as boat sheets) which provide in great detail (much more so than on nautical

charts) ocean soundings along the coast. Copies of these sheets are now available from the National Ocean Survey (C3233) for the outer coast areas from the Cape Fear River, N.C., to the vicinity of Savannah, Ga., and along the Florida coast from False Cape to Daytona Beach.

The information is important to commercial shipping, recreational craft, and coastal engineering. It also provides a picture of the sea bottom, useful in almost any study of the area, whether for engineering or scientific purposes or in connection with petroleum research and the recovery of minerals on the continental shelf.

Other data gathered in the project will be reflected later in updated nautical charts and tide and tidal current prediction tables. These data are important not only to ship navigation, but to all types of coastal engineering, including the construction of buildings and other structures, such as piers and seawalls.

The areas covered by this year's SCOPE operations include the offshore coastal region from Flagler Beach, Fla., to Brunswick, Ga., by the NOAA Ship *Mt Mitchell;* St. Helena Sound, S.C., and the waters off Cape Fear, N.C., by the *Peirce*; and St. Helena Sound to Savannah, Ga., by the *Whiting*. An instrument-equipped launch surveyed Florida's inshore coastal waters northward from False Cape. The *Ferrel* conducted estuarine circulatory studies in Georgia in the Savannah and Wilmington rivers and in the vicinity of Wassau Sound.

Elements of the Atlantic Hydrographic Party and other field units from NOAA's Atlantic Marine Center, Norfolk, Va., conducted hydrographic and coastal mapping operations from Cape Hatteras, N.C., to the vicinity of Daytona Beach, Fla. Aerial photography by the National Ocean Survey has now been carried out from Morehead City, N.C., to the vicinity of Cape Canaveral, Fla., in support of the hydrographic mapping program. The segment northward from Morehead City to Cape Hatteras will be completed in early 1974. Hydrographic surveys were conducted by the Atlantic Hydrographic Party at the Wando River, S.C., Wassau Sound, Ga., Nassau Sound, Fla., and the St. Johns River, Fla.

Commerce Fleet Sets 1974 Ocean Studies

Approximately 1,000 scientists, technicians, officers, and seamen will man 21 Commerce Department ships plus numerous smaller craft in a new season of investigations of the oceans and waters that lap the shores of the United States and foreign lands.

Their activities will take them up and down the coasts of the United States to the Caribbean and the Gulf of Mexico, across the Atlantic to Africa, off both coasts of Latin America, into the vast reaches of the Pacific, the Gulf of Alaska, and elsewhere.

They will probe the oceans, including the land beneath and the air above, the coastal waters and estuaries of the United States, the submerged continental shelves, the wrecks that dot America's shores, the treacherous currents that endanger seamen and their craft, and the water's abundant aquatic life.

Some work will be glamorous; much of it will be routine, but essential. The mysterious internal waves, which undulate below the surface of the sea, will be probed, as will the mountains, ranges, canyons, and massive fractures in the earth at the bottom of the sea. And scientists will seek additional evidence of the movement of the continents and sea floor spreading. Others will conduct investigations necessary for managing fisheries resources.

While the larger seagoing vessels are carrying on deep ocean activities, the smaller ships of the Commerce fleet will be conducting marine charting surveys, measuring the currents along the coasts and in estuaries, bays, and harbors, and scouring coastal sea lanes for submerged wrecks, pilings, abandoned equipment, coral and rock formations, and other dangers to sea commerce and recreational boating.

Still other vessels will be studying fisheries resources, conducting investigations, such as tracking fish migrations, and gathering data for predicting areas of occurrence and levels of abundance, studying environmental parameters that affect survival and fluctuations in population, and assessing and evaluating the potential for use of the various fisheries resources. Various experiments will be conducted to advance man's knowledge of the ocean's living resources and to develop or perfect assessment equipment and techniques, such as remote underwater observation equipment and diving with or without submersibles.

The ships are operated by the Commerce Department's National Oceanic and Atmospheric Administration. The NOAA Fleet supports primarily the activities of three NOAA agencies—the National Ocean Survey, the National Marine Fisheries Service, and the Environmental Research Laboratories. They are based at Norfolk, Va., Miami, Fla., Detroit, Mich., Seattle, Wash., and, for those engaged primarily in fisheries research and studies, at various ports where fisheries laboratories and centers are located.

This year, as during the past few years, NOAA scientists are continuing their research on the interrelated theories of continental drift and sea floor spreading. According to the continental drift theory, the earth at one time had one or two large land masses which began to split some 200 million years ago. The theory postulates that, as the sea floor spreads, the continents are drifting at about one inch or so a year. The drifting resulted in the separation of the supercontinents. According to a related theory, the earth's crust is made up of gigantic, grinding, constantly moving plates or segments.

Deep ocean surveys will be conducted by the NOAA Ships *Oceanographer* and *Researcher*. These and other vessels will be engaged in extensive oceanographic research projects involving studies in such widely-separated areas as the North Atlantic, Puget Sound, the Great Lakes, the New York Bight, Gulf of Mexico, Caribbean, and the central and eastern Pacific.

The studies will seek to extend man's understanding of the ocean and the atmosphere above; to evaluate the living marine resources of waters off the United States and South America; to assess the environmental impact of submerged coastal areas, such as the New York Bight; and to study the behavior of cloud clusters and their role in the larger circulation of the atmosphere. Some studies will involve other U.S. agencies and educational institutions and foreign countries. Various studies are tied in with efforts to obtain data which will help solve the problem of ocean pollution.

A study of tropical atmosphere and oceans and their effect on the earth's weather will be carried out by the Seattle-based *Oceanographer* and the Miami-based *Researcher* off the northwest coast of Africa in conjunction with ships and aircraft of 10 nations.

On the Great Lakes, the *Shenehon* will set current meters on Saginaw Bay, after which she will perform research work on the St. Clair and Detroit Rivers and lower Lake Huron, while the *Laidly*, using a newly-installed hydroplot system, will make hydrographic surveys on Lake Erie. The *Johnson* will conduct a water quality survey of Saginaw Bay early in the season and will then be shifted to chart revisory surveys on Lake Michigan. The *Virginia Key*, operating out of Miami, will conduct nearshore and coastal oceanographic studies.

Much of the work that will be done by NOAA ships in 1974 will be essential to safe navigation. Marine Charting surveys will be carried out by the *Rainier*, *Fairweather*, *Davidson*, *Mt Mitchell*, *Whiting* and *Peirce* in the waters of the Carolinas, Georgia, Florida, California, Washington, Alaska, and other areas. The *McArthur* will conduct tide and current surveys in Washington and Alaskan waters.

Essential also to safe navigation are the wire drag surveys for underwater hazards conducted in the Gulf of Mexico by the *Rude* and *Heck*. Circulatory studies will be performed by the *Ferrel* in the New York Bight, the 15,000-square-mile area of ocean waters and continental shelf that extends from Montauk Point, Long Island, to Cape May, N.J.

While these activities are underway, NOAA vessels will be engaged in important fisheries surveys and research along U.S. coasts, in the Caribbean and Gulf of Mexico, off Nova Scotia, and in the Pacific.

These vessels carry out a wide range of studies as diverse as egg and larval surveys off the east coast to studies of the abundance and distribution of groundfish in the Gulf of Alaska and Bering Sea. They gather biological data vital to international discussions and agreements on fisheries, as well as data for the MARMAP program (Marine Resources Monitoring, Assessment and Prediction), a long-range study of our fishery resources. Essentially, the mission is to estimate periodically the size of stocks in total numbers and weights and their expected yields at given levels of fishing. This is done primarily by fishery catch analysis, egg and larval studies, and juvenile and adult stock surveys.

Major marine resources being studied include shrimp, lobster, tuna, snappers, billfish, pollock, sablefish, and salmon. Included among these vessels will be the *Oregon* and *Oregon II*, *Bowers*, *Albatross IV*, *Murre II*, *Jordan*, *Cobb*, and *Rorqual* and *Delaware II*. Another seagoing vessel, the *Pribilof*, will make four supply trips to communities on the Pribilof Islands in the Bering Sea, where the Alaska fur seal herd is maintained by the National Marine Fisheries Service.

Fisheries Pollution Abatement Surveyed

The Commerce Department's National Oceanic and Atmospheric Administration (NOAA) has launched a survey to identify research projects in the United States related to reducing pollution caused by fisheries activities. It is conducted by NOAA's National Marine Fisheries Service and seeks information from wide-ranging fields; harbor studies and fish processing plant design.

An NMFS spokesman said that while each Federal and state agency has information on what is being done in its own agency, there is no single source for obtaining the broad range of information being sought in the survey. Researchers throughout the Nation were asked to describe briefly aspects of their studies and resulting publications that relate to fisheries pollution abatement. Key words are used in the survey which relate to certain species of fish, types of processing, and the pollution technology being used or under study.

Results of the survey are distributed via an NMFS publication entitled "Current Information on Fisheries Pollution Abatement Technology." The information is free to researchers, processing plant personnel, fishermen, boatowners, State and Federal officials, regulatory agencies and others having a need for such information.

CORRECTION

Portions of the paper, "Home Freezing of Seafoods" by Melvin E. Waters, *Marine Fisheries Review*, Vol. 36, No. 1, p. 1-6, were taken from a paper "Home Freezing of Seafood" by Kenneth S. Hilderbrand, Extension Seafood Technologist, Oregon State University, Corvallis, Ore., for which proper credit was not given. Lack of the reference was inadvertently overlooked when the manuscript was reviewed and submitted for publication. We regret the omission.

Kneaded Fish Product Peak Seen In Japan

The "Kamaboko," a heat-pasteurized fishcake relished by the Japanese, has shown a steady increase in production and improvement in quality in recent years. The production of "Kamaboko" and other kneaded fish products in 1972 totaled 1,156,205 metric tons, compared with the 1967 output of 911,887 tons. However, the rate of increase in production, after the 1-million-ton mark was reached in 1969, has slowed down; and in the opinion of the Executive Director of the National Federation of Kamaboko Processors Associations, the demand may have reached a peak in Japan.

About 70 percent of the steamed and broiled "Kamaboko" is made from frozen surimi (minced fish meat).

Frozen surimi production, 1965, 1971-73, and 1974 target.

Year	Land-Based Plant	Factory-ship	Total
	(Metric tons)		
1965	30,505	6,986	37,491
1971	137,000	186,000	323,000
1972	161,210	193,548	354,758
1973 (Estimate)	162,069	224,774	386,843
1974 (Target)	150,000	210,000	360,000

Since the development of surimi from Alaska pollock in 1963 as a suitable ingredient for manufacturing "Kamaboko," its demand began to sharply increase each year. The combined surimi production in Japan, on land and at sea, which recorded 37,491 metric tons in 1965, rose to 354,758 tons in 1972 and to 387,000 tons in 1973. However, because of fishing restrictions on Alaska pollock in the Eastern Bering Sea and other factors, the output in 1974 is estimated to decline to about 360,000 tons. Normally, the yield of surimi from raw fish is said to be 25 to 26 percent, but the surimi factoryship operators in the Bering Sea are hoping to increase the yield about 5 percent to offset restrictions on the catch.

Production of kneaded fish products, 1967-72.

Year	Kamaboko: Steamed	Kamaboko: Broiled	Kamaboko: Deep-Fried	Fish & Ham Sausage	Fish Hamburger[1]	Others	Total
			(Metric Tons)				
1967	294,782	171,745	267,549	164,431		13,380	911,887
1968	336,365	194,035	289,501	161,753		17,724	999,378
1969	368,016	204,290	319,191	168,789		16,904	1,077,190
1970	356,398	221,484	313,552	169,539	13,977	6,381	1,081,331
1971	379,816	238,539	322,161	165,368	14,839	6,382	1,127,105
1972	399,783	244,615	329,623	162,398	16,403	3,383	1,156,205

[1]Data not available for years prior to 1970.

Source: *Suisan Shuho*, February 15, 1974, and others.

USSR Tests Mini-sub for Fishery Research

Soviet fishery scientists are now testing *TINRO-2*, a miniature underwater vehicle to be used in studying the biological resources of the Continental Shelf, reports the NMFS International Activities Staff.

TINRO-2 was designed for deep dives and autonomous research trips independently of its mothership. It has two hulls; the inner one, made of steel, will be encased by a light-weight outer fiberglass hull. Water can be pumped in between the two hulls to act as ballast. The vehicle can move in any direction, or hover. It is equipped with television and automatic still and movie cameras.

The crew of two persons includes a pilot (who is also the commander of the vehicle) and a research scientist. The gaseous mixture inside *TINRO-2* and its air pressure are those of sea level. Food and drinking water storage space is provided for prolonged underwater research trips.

Now being tested in the Black Sea, *TINRO-2* will later undergo final tests in the Atlantic or Indian oceans. It was designed by "Giprorybflot," in the Soviet Federal Design Institute of the Fishing Fleet, and will be used primarily by the USSR Ministry of Fisheries. A number of Soviet organizations participated in designing the vehicle, but the basic responsibility for the design rests with M. Girs and V. Deriabin, both employed with the "Giprorybflot" in Leningrad. (Source: *Vodnyi Transport*, February 28, 1974.)

According to the NMFS International Activities Staff, *TINRO-2* was taken to the site of its first trials (the Black Sea, near the Crimean city of Feodosiia) in December 1973 by the scientific research vessel *Ikhtiandr*. A group of engineers, fisheries biologists, and underwater research scientists was brought together for the tests. The Director of VNIRO's[1] Laboratory for Underwater Research, Dr. Marlen Pavlovich Aronov, heads the group.

Dr. Aronov, whose specialty is fish behavior and animal physiology, has been in underwater fisheries research for more than a decade. In the late 1950's and early 1960's, while working at the Sevastopol' Biological Station, he was using underwater research techniques to study conditioned reflex reactions of certain Black Sea fishes. His side interests have led him into underwater research of Crimean Peninsula caves with a group of Moscow speleologists in the summer of 1962. During 1966-1967, Dr. Aronov was active in organizing Soviet participa-

[1]VNIRO is the Soviet Federal Scientific Research Institute for Fisheries and Oceanography in Moscow.

tion in a Soviet-FAO Seminar on Gear Technology in Moscow, and an FAO Conference on Fish Behavior in Relation to Fishing Techniques, held in Bergen, Norway.

The *TINRO* class of underwater research vehicles has been so named after the Soviet Pacific Scientific Research Institute for Fisheries and Oceanography (located in Vladivostok), whose Russian initials spell "TINRO."[2]

The *TINRO-1* and *TINRO-2* projects were first mentioned in the Soviet media in 1966. In January of that year, *World Fishing* (U.K.) reported from Soviet sources that the USSR would "soon" have two new underwater laboratories. By 1968, TINRO biologists were hoping that one of the two underwater vehicles would be operational by 1970, or 1971 at the latest. The construction of *TINRO-2* was delayed by technical and bureaucratic problems for three to four years, and there is no evidence that *TINRO-1* will be built at all.

The Soviets have constructed, in addition to *TINRO-2*, several other small submersibles for fisheries research. Some of these, like *Atlant-1*, *Atlant-2*, *Sever-1*, and *Sever-2*, have been widely publicized in both the Soviet and Western media. The smaller underwater vehicles are deemed by Soviet fisheries scientists as much more convenient research vehicles than was the huge *Severianka*, a naval submarine converted into a fisheries research submarine. The *Severianka* is not only too large and expensive, it is also too cumbersome for effective underwater fisheries research.

The Norwegian Fishing Industry

The basis for the Norwegian fishing industry is its very long coastline and the rich fishing grounds with temperate waters thanks to the Gulf Stream, according to a report by Knut Vartdal, Norway's Director General of Fisheries.

The fishing on the coastal grounds is to a large degree based on rich shoals of fish migrating to the grounds for spawning or feeding. This, says Vartdal, has determined the development of fishing craft and fishing methods. In addition, fishing activities have through decades been carried out on the open sea in Skagerrack and the North Sea, in the Norwegian Sea and the Barents Sea, off Greenland, Newfoundland and in other parts of the Atlantic, and the last few years also off West Africa.

The landings by Norwegian fishermen in the last 5-year period varied between 2.2 and 2.9 million tons. Approximately ⅔ of the catch were used for production of meal and oil. This is mainly due to the big catches of capelin.

During the 4-year period 1969-1972 the average catch (in tons) for the 6 most important species were:

Capelin	1,226,870
Mackerel	337,800
North Sea herring	175,930
Arctic cod	156,576
Norway pout	132,879
Saithe	111,765

The average firsthand value (in 1,000 kroner) for the 6 most important species were however different:

Arctic cod	259,800
Capelin	252,310
Mackerel	135,799
Saithe	89,050
North Sea herring	67,961
Cod (from distant waters)	65,656

THE RESOURCES

The main problem of Norway's fishing industry is the overfishing of the most important species in the North Sea, the Northeastern part of the Atlantic and the Barents Sea, says Vartdal. The efficiency of gear and equipment has lead to a very serious reduction of many of the main stocks of fish, including some of the following species.

Arctic Cod

This stock is in a period of increasing recruitment of young cod. However, the stock of mature cod is decreasing because of poor year classes from 1965 to 1968 and because of heavy fishing the last years. Therefore, a regulation of the international exploitation of the Arctic cod is of great importance. Norway, the United Kingdom, and the USSR have, after many years of negotiations, agreed on a total quota for 1974 of 550,000 tons, which should lead to a rather considerable reduction of the fishing effort.

However, this quota regulation is far from a satisfactory solution, according to Vartdal. Too much of the catch consists of young cod, which is a result of too small mesh sizes, and also evasion of the mesh size provisions.

Capelin

Besides cod, capelin is now the most important kind of fish for the Norwegian fishing industry and the main basis for the Norwegian purse seiners.

Up to now, Norway has been alone in exploiting the capelin. To prevent overfishing, Norway has through several years imposed a number of national regulations such as closing of spawning grounds, quotas on total catch, minimum size of fish, and closed seasons. So far, the regulation measures have prevented depletion of the stock.

As soon as other nations start fishing for capelin, the regulation and management of the capelin fishing will become an international problem.

Atlanto-Scandian Herring

Up to the end of the 1950's this herring stock was the basis for very rich fisheries on the west coast of Norway. This stock is now very small. Since 1971 there has been an agreement between Iceland, USSR, and Norway limiting the catch. If this

[2]TINRO is one of VNIRO's five regional research institutes; it specializes in fisheries research in the Pacific and Indian oceans.

policy is continued, there is a chance that this stock can be rebuilt. This will, however, no doubt take years.

North Sea Herring

During several years this herring stock has been fished intensively. This has resulted in catches being halved. More serious is the fact that most of the catches consist of young herring. Up to now, it has not been possible to come to an agreement between the interested countries.

In the meantime, Norway has, alone, introduced a voluntary national regulation on this fishery, according to Vartdal. Norwegian fishermen are now proposing such national regulations, and officials hope that international regulation measures will be introduced without further delay.

Mackerel

Most of the mackerel landings from the North Sea are caught by Norwegian fishermen. Norway has imposed very strict regulations on this fishery. This has enabled them to rebuild the stock after a period of considerable overfishing.

The Norwegian fishing industry is now hoping that the Law of the Sea Conference will give the coastal states rights to establish economic zones of 200 nautical miles in order to get better management of the fish resources. The cooperation between the European countries in order to prevent over-fishing has taken a long time and too often have the results come too late, Vartdal says. With economic zones of 200 nautical miles the coastal states will be in a position to introduce regulatory measures which keep the fish production at the maximum sustainable yield, he adds.

FISHERMEN AND FISHING FLEET

Norway has approximately 35,000 fishermen out of which 10,000 fish part-time. This is a great reduction since World War II. In spite of this reduction the landed weight has increased considerably in the same time. This means that the productivity has increased and combined with higher prices; this has led to a great increase in the fishermen's income.

Norwegian fishermen are to a great extent owners of their boats. This has for a long time been the declared aim of the government and the fishermen's organizations. The fleet comprises more than 7,000 decked wooden vessels and 600 decked steel vessels totalling 300,000 gross reg. tons. The number of vessels under 100 feet has gone down, on the other hand the number of vessels over 100 feet has increased. There are purse seiners, long-liners, and fresh fish or factory trawlers.

FIRSTHAND SALES AND EXPORTS

In the late 1920's the prices were very low for most of the fish, especially for herring. The herring fishermen therefore formed two fishermen sales cooperatives. This was the start of the organized firsthand sale of all fish landed in Norway. Before World War II Parliament had passed the so-called Raw Fish Act. Owing to this law Norway now has sales organizations in Norway, and no fisherman is allowed to sell outside any of these cooperatives.

Between 80 and 90 percent of the Norwegian catch is exported. In 1973 the export value passed 3 billion kroner, making up nearly 15 percent of the total Norwegian exports. The general world food shortage has given high prices for the Norwegian fish products resulting in high earnings for both the fishermen and exporters. Provided that the future will bring better management of the fish stocks in the North Atlantic, the Norwegian fishing industry is fairly optimistic about the future.

Peru Meets March Anchovy Quota

Peruvian fishermen reached their full quota for the first period (March 5-March 27) of anchovy fishing, with a catch of 500,000 tons, according to the U.S. Embassy, Lima, Peru. While the harvest was generally satisfying, the degree of recovery of the industry remains uncertain. Distribution along the central coast was good, but the average daily catch declined from about 40,000 tons in the first two weeks to 25,000 tons during the last week. (Each "week" lasted only 4 days, Tuesday-Friday.) A seasonal decline appeared in the South, but the northern (Chimbote) region

Japan Eyes Gulf Coast Croakers for "Kamaboko"

Japanese "Kamaboko" (fishcake) processors, who are looking for new sources of raw fish supply for their products, are investigating the U.S. Gulf Coast croaker. They plan to obtain samples for laboratory studies to determine their suitability for "Kamaboko" production. The U.S. croaker came to their attention in the summer of 1973 when two scientists from a U.S. fishery laboratory went to Japan and discussed efficient utilization of the Atlantic croaker with the Fisheries Agency and the Federation of Kamaboko Processors Associations. In December 1973, discussions were again held when the U.S. delegates to the FAO conference on fishery products made available samples for laboratory studies. Opinion among the Japanese processors is that the Gulf croaker are not as ideal as the croaker taken in the East China Sea. However, they believe the U.S. species have good elastic characteristics needed for "Kamaboko" manufacture and estimate that the Gulf Coast could provide around 50,000 tons of supply annually.

Source: "Minato Shimbun, March 20, 1974.

yielded much less than expected, indicating that this area is still recovering.

The anchovy size was reported good. Fish meal recovery was reported at 21.9 percent, producing thus far, an estimated 109,000 tons. Oil recovery is believed to be over 3 percent or 15,000 tons. Peruvian authorities (EPCHAP) were authorized to renew export of both fish meal and oil beginning 14 March.

Japanese Hatch Eels, Sea Urchins

A Hokkaido University professor is reported to have succeeded in hatching eels in a laboratory, notes the NMFS Statistics and Market News Division. A professor of the University's Fisheries Department extracted a hormone from the pituitary gland of a salmon and gave a weekly 35-milligram injection to grown female eels. After 11 injections, one of the eels laid eggs and after 40-50 hours the researcher applied eel milt to the eggs. Out of this, 100 fry 3.5 mm in length were hatched, but only half survived. The seawater temperature was maintained at 18°C before the spawning and was kept from 23 to 25°C afterwards. The 2-month-old eel fry were fed egg yolk and lobster eggs.

The Fukushima Marine Experiment Station, Kyushu Island, Japan, is also reported to have succeeded in its year-long attempt to breed sea urchins. Starting with some 300,000 eggs of the common green urchins in a seawater tank in November 1972, some 2,500 sea urchins over an inch across were hatched. Scientists induced the female urchins to ovulate with injections of potassium chloride.

Cuban Fishing Fleet Expands

The Astilleros Construcciones shipyard of Vigo, Spain, has started the construction of a series of 21 factory trawlers for the Cuban fishing fleet. The order was initially placed for only 10 trawlers of the *Tacsa-95* class, 3 of which have already been delivered. Since *Mar Del Plata*, one of the delivered trawlers, was destroyed in a fire, the Havana authorities decided to replace it and order 10 more vessels in addition to the ones already ordered, thus raising the total to 21 trawlers. Sixteen of the vessels will be built in the Astilleros shipyard and 5 in Hijos and Barreras shipyards. Delivery will start in 1975 and should be completed by 1977. The *Tacsa-95* trawlers were conceived by the firm Tecnaco, a subsidiary of Astilleros.

Characteristics of the trawlers are: 106.70 meters long (95 meters long between perpendiculars), 14.50 meters wide, powered by 4,000 hp Deutz engines (built under license by Barreras in Spain), planned speed 14 knots, and storage capacity 2,000 tons of frozen fish and 240 tons of fish meal. The vessels are equipped with Raader fish-processing machinery and with a Schlotterho fish meal plant utilizing leftovers and trashfish. They can fish with pelagic or bottom trawls.

Source: *France Péche*, No. 186, December 1973-January 1974, pp. 145.

Fishery Notes

Canadian Pair Seining: Off-season Source of Income for New England Lobstermen?

Two Point Judith, R.I., lobstermen are trying a fishing method that may provide them with income during the off-season when their boats are not normally in use. If the Canadian pair seining technique proves successful, it could provide income for New England lobstermen with 35- to 55-foot vessels from January to June when lobster fishing is poor. Canadian lobstermen have used the seining technique successfully for several years on both coasts.

Bruce E. Kopf, skipper of the 55-foot steel vessel, *Spartan*, and Charles W. Carpenter, skipper of the 55-foot steel *Atlantic Queen* announced the trials in March at the annual Fishermen's Forum at Galilee, R.I. They said they had modified their vessels and had some success with Canadian pair seining on two days of trials.

Fishing on the second day with the new gear, the Rhode Island skippers caught 2,500 pounds of marketable fish, enough for a good economic return. But it would take at least another month of trials before the feasibility of the method could be fully tested for the Rhode Island coastal waters, according to Robert E. Taber, University of Rhode Island commercial fisheries specialist.

Mr. Taber, who is assisting with the project, said that sustained catches of 2,000 to 4,000 pounds per day are needed if the pair seining method is to be economical. Canadian pair seining is performed by two vessels pulling cable and a bottom net between them. The vessels drag thousands of feet of cable that is first strung out in a crescent shape along the ocean bottom and then pulled into a "V" shape to herd fish into the path of the net.

For two lobster boats to use the method, they must be modified at a cost of about $6,000, which includes all gear and nets, Mr. Taber said. The vessels may still be used for lobster fishing, he said. Nets and advice on their use have been provided for the trials by the Marine Advisory Service, part of the URI Sea Grant program, Mr. Taber said. The advisory service is also employing the services of Capt. George Thomson, an expert on Canadian pair seining from Lossiemouth, Scotland.

LOWER CATCH SEEN FOR CHESAPEAKE BAY CRABS

Chesapeake Bay landings of blue crabs are expected to remain near 50 million pounds a year for the next

two years, according to the head of Virginia Institute of Marine Science Department of Crustaceology. The department head, who is well known for his accurate predictions of blue crab abundance and production, based his figure on estimates of the present abundance of juvenile and adult crabs.

The researcher explained that although some blue crabs in the Chesapeake Bay spawn in late April and some in early October, intensive spawning begins in June and ends in late August. In a year of normal temperature and rainfall, large numbers of crabs reach maturity by early September, 14 months after hatching.

Between September (when maturity is attained) and the following August, most adult crabs die from natural causes or are removed by fishing. "Thus, we can expect that in the Bay the commercial fishery exploits a new crop every 12 months, between September and the following August," the researcher said.

"Catch since September 1973 has been only two-thirds of the long-term average, and there should be a temporary high catch from May through August, derived from a later-than-normal hatch of crabs in 1973. This increase is expected to be short-lived, however, and catch from September 1974 through August 1975 should be about 50 million pounds," the researcher stated.

Alaska King Crab Catch Rises in 1973

The Alaska king crab harvest in 1973 totaled 76 million pounds and brought fishermen more than $40 million, the Alaska Department of Fish and Game reports. The harvest is the largest since 1968 and totals two million pounds more than the 1972 catch. Major king crab fisheries in the Bering Sea, Kodiak, Alaska Peninsula and Unalaska areas were highly successful. Quotas were quickly attained through improved efficiency and increased effort in all registration areas.

In the Bering Sea, 67 vessels harvested the 23 million-pound quota in 86 days. In comparison, 21 million pounds were harvested over a 10 month period in 1972.

The Kodiak area opened on Aug. 15 with 125 vessels participating. The season was closed 10 days later after 10.3 million pounds were taken from a 13 million-pound quota in the Southern district. This district was reopened during October for eight days and an additional two million pounds were harvested. In the Northeast and Shelikof districts of the Kodiak area, the harvest was 1.6 million and 800,000 pounds, respectively. The Kodiak area king crab catch totaled 14.7 million pounds.

The South Peninsula king crab season opened in mid-August and closed Sept. 28 in the Unimak Bight district, Oct. 17 in the Central district and Jan. 15 in the West Chignik district. The total king crab catch for the South Peninsula area reached 4.5 million pounds, slightly above that of the previous year.

In the Unalaska area the 24 day king crab season produced good fishing in all districts, with the Egg Island district showing excellent catches. The total harvest for all districts was 13.5 million pounds by 55 vessels. The Adak, or Area R, season opened on Nov. 1 and was closed by the department by emergency order on Dec. 6 when it became evident to biologists monitoring the fishery that the king crab stocks in the area were at low level of abundance. The eight million pound harvest from this major production area had fallen far short of the anticipated level and the closure was necessary to conserve the resource. Subsequently, a portion of the southern and western Aleutians king crab areas were reopened on Feb. 1 on the basis of exploring the availability of stocks in areas unfished during the initial open season. Catches through the Feb. 26 closing date in these areas were estimated to be slightly in excess of one million pounds.

Publications

New York Bight User Services Publication

A new catalog describing available products and services associated with the New York Bight, a marine area of critical economic and environmental importance, has been issued by the Environmental Data Service—a part of the Commerce Department's National Oceanic and Atmospheric Administration.

Entitled **NOAA Products and Services Pertaining to the New York Bight,** the publication is a by-product of the Marine Ecosystems Analysis (MESA) Program under the Office of Coastal Environment—a project initiated by NOAA in 1973 to study the waters extending from Montauk Point, L.I., to Cape May, N.J., and from the coastline to the edge of the Continental Shelf. This is perhaps the most complex and heavily impacted coastal marine area in the United States.

The catalog is divided into six service sections. Subjects covered are environmental prediction and warning services, environmental satellite information, marine resources, marine description, mapping and charting, marine data services, and library and information services. The four appendixes contain a listing of addresses to help the user identify the sources offering the various products and services, a listing of general catalog-type publications that inform the user about products in special interest areas, a glossary of acronyms, and a subject index in alphabetical order.

Copies of the publication may be obtained from the Project Manager, MESA New York Bight Project, Marine Sciences Research Center, Bldg. J, State University of New York, Stony Brook, NY 11790.

Alaskan Oil Impact Booklet Published

The effects of oil resource development on northern plant life is the subject of a 95-page booklet published by the University of Alaska's Institute of Arctic Biology in Fairbanks. It is entitled **Proceedings of the Symposium on the Impact of Oil Resource Development on Northern Plant Communities,** and was published in 1973 following the 23rd Alaska Science Conference held on the University's Fairbanks campus the year before.

Included in the published research reports is a study of revegetating disturbed tundra and taiga (subarctic forest areas) at eight sites along the route of the proposed 800-mile trans-Alaska pipeline. Dr. Keith Van Cleve, associate professor of forestry at the University, gives results of three years of work, and reports that considerable success was obtained using grass seed to revegetate disturbed sites south of the Happy Valley-Sagwon area. More northerly sites, however, may require additional watering or mulching with organic matter to help retain moisture. Plant species were selected with assistance from the University's Institute of Agricultural Sciences; useful species tested included annual rye grass, meadow foxtail, arctared fescue and nugget poa grass.

A difference in the effect of crude and refined oil was noted in another paper in the publication. B. H. McCown, formerly of the Institute, and F. J. Deneke of the U.S. Army's Cold Regions Research and Engineering Laboratory at Ft. Wainwright were among a group of scientists who reported that on the North Slope, particularly, certain native sedges—grasslike marsh plants—seemed relatively tolerant to crude oil. Plants treated with five liters per square meter (slightly less than five quarts on an area approximately one yard square) caused a dry-weight decrease of only 19 per cent one year later. Refined oil, however, seemed to be potentially more destructive than crude. It has remained in the subsurface layers of soil for years along the route of pipelines in interior Alaska. The authors point out, however, that efforts to revegetate in these areas covered by a mat of dead plant material is often harmful, because the dead material acts as insulation to prevent the melting of permafrost which leads to erosion.

Another report in the publication tells of the effect of natural oil seeps on microscopic plant and animal life in small ponds. Drs. Robert J. Barsdate and Vera Alexander of the University's Institute of Marine Science participated in that study which indicated that although relatively fresh oil in the water caused a decrease in plant life in the ponds, water in contact with old oil-tars and asphalts had a greater amount of algae and other simple forms of plant life. The microscopic animal life that would ordinarily feed on the plants decreased when water was in contact with oil of any age, however, and the researchers concluded that the increase in plant life was possible due to the decrease in grazing pressure. Publication of the proceedings of the symposium was assisted by a joint grant from the Life Sciences Division of the Army Research Office, and the Alyeska Pipeline Service Company.

Marine Journal Gets New Editors

Dr. William J. Richards, of the Southeast Fisheries Center, NMFS, Miami, Fla., has been appointed editor of the *Bulletin of Marine Science*, a quarterly journal of the Rosenstiel School of Marine and Atmospheric Science, University of Miami. James B. Higman of the University of Miami will serve as assistant editor. The new editorial board includes Drs. Frederick M. Bayer and Michael R. Reeve, University of Miami; Dr. Ivan Goodbody, University of the West Indies, Kingston, Jamaica; and Dr. Reuben Lasker, Southwest Fisheries Center, NMFS, La Jolla, Calif.

The *Bulletin* is dedicated to the enhancement of high quality research in the marine sciences, particularly to those relating to tropical and subtropical waters. Preference is given to papers of primarily biological interest, but relevant manuscripts in the physical, chemical, and geological sciences are also welcomed. Contributions of general and theoretical significance will be considered for publication along with papers of economic or applied aspects of commercial fisheries.

New subscription prices for the *Bulletin* per volume of four issues will be: Volume 24 (1974), institutions will continue at $32, individual subscriber rate will return to $18, and a new student rate will be $9. Due to increased costs, volume 25 (1975) may be subscribed by institutions at $50, individuals at $20, and students at $10.

Manuscripts should be submitted to the Editor, *Bulletin of Marine Science*, Rosenstiel School of Marine and Atmospheric Science, 10 Rickenbacker Causeway, Miami, Florida 33149. Subscriptions should be submitted to *Bulletin of Marine Science* Subscription Office, Box 368, Lawrence, Kansas 66044.

"Freshwater Fishes of Canada" is Available

A new book entitled **Freshwater Fishes of Canada,** has been published by the Fisheries Research Board of Canada. The authors, W. B. Scott and E. J. Crossman, have done an exhaustive and complete compilation of information on Canadian freshwater species, their distribution, biology description, nomenclature, and relation to man. Copies may be ordered by mail from Information Canada, Ottawa, K1A0S9. The price is $9.75 per copy.

Editor's Comments

It Shouldn't Have Happened, But It Did

• I hope that those of you who read Jon C. Rittgers's "Diversification Means Progress in the Gloucester Fishing Industry" in the March number of *Marine Fisheries Review* had a mirror handy when you got to page 15. Only with its aid could you have made much sense of Figure 4. For those of you who did not, here is the way it should have appeared:

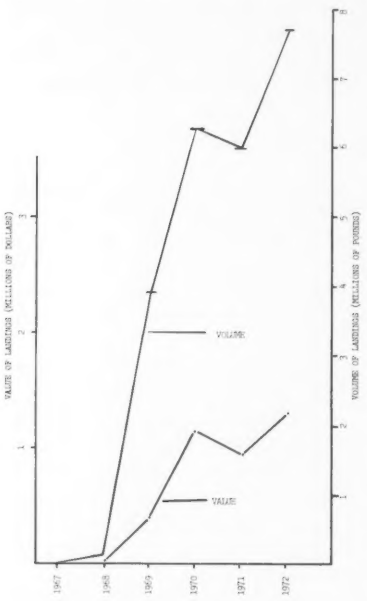


Figure 4.—Volume and value of shrimp landings in Gloucester, 1967-1972 (millions of pounds and millions of dollars).

The mistake arose from a last-minute attempt to correct a minor error on page 15 (the word "VALUE" in Figure 3 had been misplaced). It should serve as a warning against too insistent a perfectionism, I suppose. The mathematical odds, with printers as good as ours, against such a blunder appearing in print are fantastically high. One might as well attribute it to the onset of spring or the prevalence of evil spirits as anything else. Anyhow, I apologize to Mr. Rittgers and our readers and hope only that should further mistakes occur, they be no more critical than—and even as laughable as—this one.

• Those of you who are addicted to reading the fine print are aware that, as a rule, reprints of articles from *Marine Fisheries Review* ". . . in limited numbers, are available from D83, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235." (Actually, they are available from Sarah Kroll, a very nice and competent person who works for D83 and sees that these requests are promptly filled. She often goes out of her way to locate not only reprints from *Marine Fisheries Review*, but also any other publications issued by the National Marine Fisheries Service and its predecessor, the Bureau of Commercial Fisheries: she is a blessing.)

However, with Dave Almand's article "Publications and Services of the National Marine Fisheries Service," which appeared in the March number, an exception has been made. The article is so useful to everyone interested in fisheries that reprints have been made available to all of our centers, laboratories, and extension offices. If you need a copy, simply get in touch with the NMFS office nearest you and it should be able to find one for you.

For other articles appearing in *Marine Fisheries Review*, the invaluable Ms. Kroll remains your best source. If her supply of a paper is gone, however, you might be able to obtain one by writing the author or his laboratory. Our office, by the way, does not distribute copies of reprints: if you write to us, though, we shall be glad to forward your request to Ms. Kroll.

• Next month's *Marine Fisheries Review* will have a slightly different look to it than that to which you have become accustomed. In order to make better use of our precious paper supply, we are enlarging the type area and changing some of our type specifications. We hope to achieve a better looking page and be able to pack more information in each column than in the past. I hope that readability does not suffer: if you think it does, please let me know.

• By the time these comments appear in print, the Superintendent of Documents should have available for purchase the first four sections of the "Anglers' Guide to the United States Atlantic Coast," by Bruce L. Freeman and Lionel A. Walford of the NMFS Middle Atlantic Coastal Fisheries Center, Sandy Hook Laboratory.

These publications are the result of several years' unremitting work. They contain written descriptions of the fish, fishing grounds, and fishing facilities of the Atlantic coast from Maine to Key West. Also, each section of the coast is treated in a detailed map, printed in color, that tells the angler what fish are caught in what areas.

Section I covers the region from Passamaquoddy Bay, Maine to Cape Cod. The SupDocs stock number is 0320-00068. Section II (stock number 0320-00070) covers Nantucket Shoals to Long Island Sound. Section III (stock number 0320-00071) covers Block Island to Cape May, New Jersey. Section IV (stock number 0320-00072) covers Delaware Bay to False Cape, Virginia.

The Anglers' Guides are oversized —14¼ by 16½ inches—in order to incorporate all the detail that goes to make for better fishing. The remaining Sections, covering the rest of the U.S. Atlantic coast, are in press.

A comparable volume, dealing with angling off the U.S. Pacific Coast and in Hawaii, is in preparation at the NMFS Tiburon Fisheries Laboratory and should be available for purchase before the end of 1974.

T.A.M.

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